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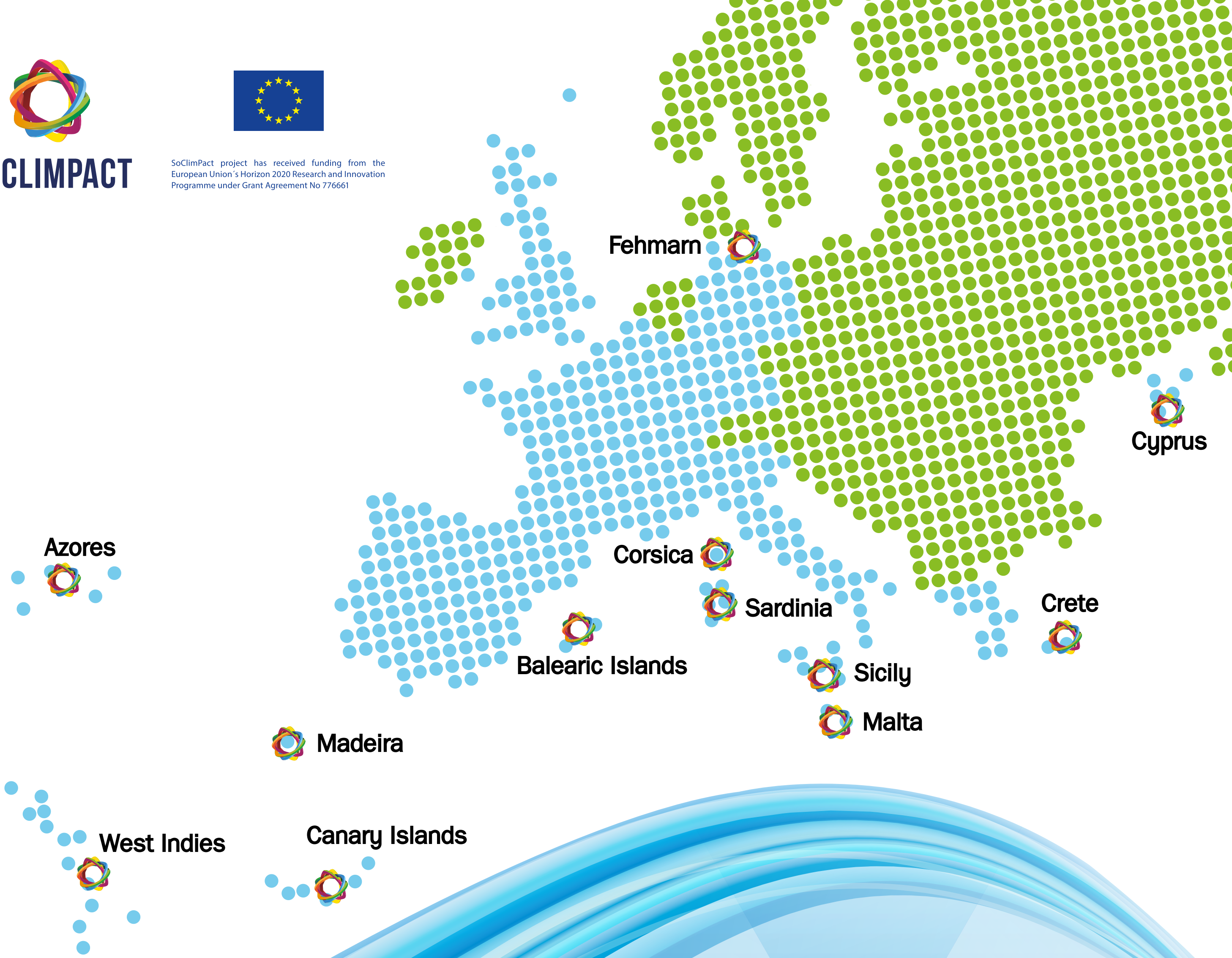

Downscaling climate change impacts, socio-economic implications and alternative adaptation pathways for Islands and Outermost Regions

Mc Graw Hill

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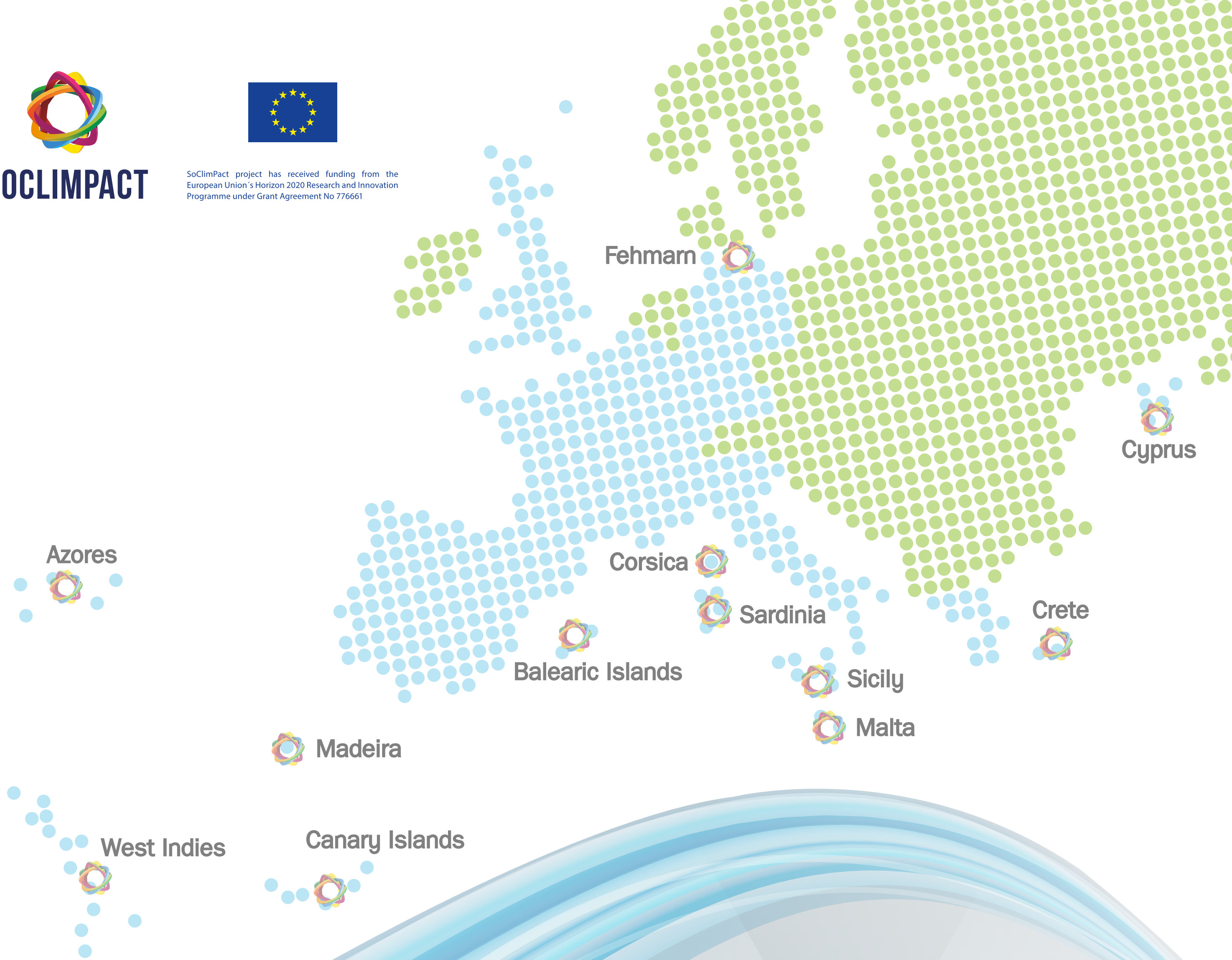

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AKNOWLEDGMENT

This publication has been supported by the European Union's Horizon 2020 research and innovation programme under grant agreement No 776661, project "SOCLIMPACT - DownScaling CLImate imPACTs and decarbonisation pathways in EU islands and enhancing socioeconomic and non-market evaluation of Climate Change for Europe, for 2050 and beyond".

Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the book, or in the decision to publish the results.

Citation: Leon *et al* (2021). *Downscaling climate change impacts, socio-economic implications and alternative adaptation pathways for islands and outermost regions.* Madrid: McGraw-Hill . https://doi.org/10.5281/zenodo.5141549

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28023 Aravaca (Madrid)

Editor: Cristina Sánchez Sainz-Trápaga
Sales Manager Higher Education: Pere Campanario Oliver
General Manager (South Europe): Álvaro García Tejeda
Development team: Diseño y Control Gráfico
ISBN (print): 978-84-486-2566-5
ISBN (digital): 978-84-486-2565-8
MHID: 978-000-85-0296-6

Website: https://soclimpact.net/

Executive Summary

This book provides a comprehensive overview of the future scenarios of climate change and management concerns associated with climate change impacts on the blue economy of European islands and outermost regions. The publication collects major findings of the SOCLIMPACT project's research outcomes, aiming to raise social awareness among policy-makers and industry about climate change consequences at local level, and provide knowledge-based information to support policy design, from local to national level. This comprehensive book will also assist students, scholars and practitioners to understand, conceptualize and effectively and responsibly manage climate change information and applied research. This book provides invaluable material for Blue Growth Management, theory and application, at all levels. This first edition includes up-to-date data, statistics, references, case material and figures of the 12 islands case studies. ¨Downscaling climate change impacts, socio-economic implications and alternative adaptation pathways for Islands and Outermost Regions¨ is a must-read book, given the accessible style and breadth and depth with which the topic is dealt. The book is an up-to-date synthesis of key knowledge on this area, written by a multidisciplinary group of experts on climate and economic modelling, and policy design.

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Introduction

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and innovation programme under
Grant Agreement No 776661

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This book presents a comprehensive overview of the climate change impacts on 12 European islands and outermost regions. Each chapter contains information of each island, which is the result of the significant work accomplished by 24 partner institutions of the H2020 Research and Innovation Action - SOCLIMPACT ¨Downscaling climate impacts and decarbonisation pathways in EU islands, and enhancing socio-economic and non-market evaluation of climate change, for 2050 and beyond¨. The decision to study islands lies on the particularities and the significant economic disadvantages of these territories with respect to the mainland, which hinder their progress towards the goals of sustainable development set by the European Union (EU). Besides, the coarse spatial resolution of many currently available projections of future changes in climatic parameters makes it difficult to derive valid statements for many of the smaller islands[1]. This lack of knowledge limits the successful implementation in islands, of the current efforts addressing decarbonisation strategies in Europe.

At the same time, in the case of small islands, the social homogeneity and cohesion typical of insular communities, as well as their openness to explore new development trajectories, could also prove effective in inducing greater flexibility and decision-making efficiency, thus enhancing local coherence between natural resources protection, human capital endowment and the institutional context, and favouring the implementation of environmental-oriented policies that reduce both the exposure to external economic fluctuations and the vulnerability to climatic disasters and climate change (Deidda, 2016). From this perspective, traditional reactive strategies, usually aiming to design adequate compensations for islands' structural disadvantages (i.e., subsidization of transport costs), need to be progressively accompanied by novel proactive and sustainable initiatives, including economic diversification, technological and management innovation in traditional activities, and the development of new remunerative sectors, through mid- and long-term interventions that also prioritize the protection of the natural environment (Deidda,2016). Thus, by implementing "pilot policies" in these territories, EU islands can become the masterpieces of European strategies, generating in turn a real added value at EU level.

Twelve European islands and outermost regions are analysed: Azores (Ilha do Faial, Ilha de Sao Miguel e Ilha do Pico), Balearic Islands (Mallorca), Baltic Islands (Fehmarn), Canary Islands (Gran Canaria), Crete, Cyprus, Madeira, Malta, Sicily and French West Indies (Martinique and Guadeloupe). In Europe, the highest levels of endemism are reached in the Macaronesian islands (Canary islands, Madeira and Azores) with their unique blend of North Atlantic, African and Mediterranean biogeographic influences and special vegetation types such as the humid evergreen laurel forest and the dry Canary pine forests[2]. Climate change, thus, contributes to the progressing decline of their extraordinarily rich biodiversity.

Among the sectors of relevance to insular economies that are exposed to climate change, this book focuses on four blue economy sectors: maritime transport, tourism, energy and aquaculture for its sector-specific analysis of climate change related impacts. This is done for many reasons:

i) the impossibility to cover all the blue economy activities,

ii) comparability potential of the four selected sectors between islands,

iii) the studied islands rely heavily on the tourism sector. At the same time, most of these regions rate among the top most popular destinations for non-EU residents. Climate change will cause important changes in the tourism visitation seasonality of these islands (Primo *et al.*, 2018),

iv) seaports play a crucial role in the European economy positioning European islands as transportation hubs for the vast majority of goods transported around the world.

v) these islands have vast amounts of renewable energy sources that may provide showcases for successful 100% renewable energy supply. This is a challenge that can be addressed through storage or backup plants (which can be itself renewable energy plants), but also taking advantage of forecasting demand increases, and estimating increased complementarity of PV and wind energy for the very different consumers and prosumers characteristics,

vi) the contribution of aquaculture to fish production has grown from 25.7% in 2000 to 46% in 2018. However, in Europe, the share of aquaculture in fish production is only 17% and the EU is the largest importing market (FAO 2020). Therefore, there is a growing interest to move large scale aquaculture operations further out into the sea, which has transformed the sector into an innovative research field, which requires advanced solutions spanning a wide range of technical, social and managerial competences (Buck and Langan, 2017). This goals is conditioned by the future climatic changes to which the marine environmet will be exposed. Environmental conditions in specific sites will not be appropriate for all candidate species, and the early assessment of the ranges of key variables (e.g., water temperature, salinity, nutrients, currents) is, therefore, essential for a sound enterprise planning.

The introduction of direct economic impacts on these four blue economy sectors due to biophysical damages were then incorporated into the macroeconomic modelling frameworks to assess climate change consequences on GPD, employment, consumption, investment and other 14 sectors. It aims to helping islands to fill-in some of the knowledge gaps that

1 Council of Europe – "Biodiversity and Climate Change".

2 Communication of the IUCN: "Climate Change and Biodiversity in the European Union Overseas Entities".

still hinder the design of custom-tailored adaptation options and the emergence of fast growth opportunities in the marine-maritime context (see **Figure 1**).

Next section presents an overview of the four blue economy sectors, their significance for the European islands, as well as existing evidence on their vulnerability to climate change impacts. The following section is dedicated to describe the methodology utilized for the study of climate change impacts on the 12 islands case studies. Chapters one to twelve presents a comprehensive overview of the results by island's case study. These chapters also include a description of the present climate and risks in each island, and the sectoral and macroeconomic projections for the 12 islands. Current limits and obtacles in the islands, and recommendations for the enhancement of resilent capacities are provided as part of each island case study. The last two sections conclude and list the references.

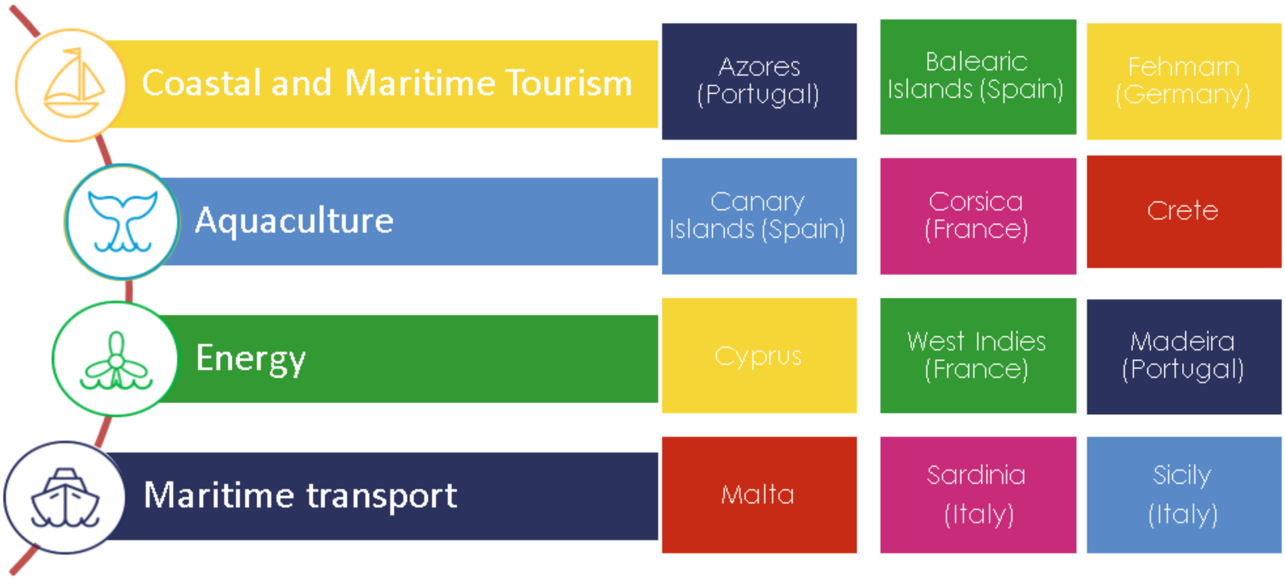


Figure 1. A sector and island approach.

Overview of the Blue Economy Sectors in the European Islands

Maritime Transport

Maritime transport is defined as the carriage of goods and passengers by sea-going vessels, on voyages undertaken wholly or partly at sea. It is often considered as the backbone of the world economy, with 80% of the global trade volume passing through ports (Asariotis & Benamara, 2012). For islands, the transport of goods and passengers by ship is even more essential. At the same time, maritime transport contributes to climate change through its carbon emissions which are found to be near 3% of the global CO_2 equivalent emissions (Smith *et al.*, 2015). Compared to land and air transport, it is the (economically and ecologically) most effective way of distributing goods globally.

A changing climate will challenge maritime transport to adapt to future risks and lower its emissions. The maritime transport is one of the key EU blue economy sectors, since Europe is amongst the leading maritime centers in the world with 329 key seaports along its coastline, and controlling around one-third of the world's merchant fleet[1]. Ports are vital gateways, linking European transport corridors to the rest of the world. As 75% of European external trade transits through EU ports, the shipping sector plays a major role in connecting the European market with its trade partners. According to the European Union's Statistical Office (EUROSTAT) and other online resources, for Mediterranean countries including Cyprus, Greece and Malta there is a significant direct contribution (3-10%) of the maritime transport sector to the total Gross Value Added (GVA). The EU maritime sector has a multiplier effect of 2.6. Hence, crudely speaking, for every 1 euro spent in this industry, another 2.6 euros are created.

In addition, there is a very strong linkage with other vital economic sectors such as services, tourism, energy, supply of goods, etc. For every €1 million the EU shipping industry contributes to Gross Domestic Product (GDP) itself, it creates a further €1.6 million elsewhere in the European economy.

According to EUROSTAT data, the sector directly employs nearly 250,000 persons (or 0.1% of the EU-27 workforce). About 20% of the total employment in the EU shipping industry are shore-based, while the rest 80% is based at sea. Besides the transport of goods within the EU territories and overseas, the maritime sector is also important for the transportation of passengers and the connection between different countries or between remote islands and the mainland.

The whole range of potential impacts of climate change on ports operations and through put is still under study and it remains a high degree of uncertainty about it[2]. Various climate change stressors can affect both harbour infrastructure and ships on-route. For example, ports are vulnerable nodes of maritime transport as they are strongly affected by rising sea-levels, which in turn affect port facilities and increase the risk of flooding. Sea-level rise has accelerated in the last century and will rise by 0.43 to 0.84 m until 2100, depending on the emission scenario (Pörtner *et al.*, 2019). Due to ocean dynamics and the Earth's gravity field, there will also be regional differences in sea-level rise in the order of 0.1 m (Asariotis & Benamara, 2012). The causes of sea-level rise are the thermal expansion of water and the melting of glaciers due to the increase in global mean temperature (Vermeer & Rahmstorf, 2009).

Maritime transport can also be affected by climate change through the increase in the intensity of extreme weather events including tropical-like cyclones. According to climate projections, tropical cyclones are not expected to change significantly in frequency but in intensity due to rising sea-surface temperatures (Pörtner *et al.*, 2019). The resulting extreme winds and waves can harm ships, but also cause damage and flooding of ports, especially in combination with sea-level rise (Hanson & Nicholls, 2012). Besides the risks for maritime transport due to climate change, a reduction of sea ice extent in the Arctic offers the opportunity to open up a new shipping route, which, for example, shortens the sea route between Europe and East Asia by about 50% (Hong, 2012).

Climate hazards such as sea-level rise or extreme weather events of increased intensity (e.g., windstorms, floods) can impose direct biophysical impacts. These can include floods on ports, damage to storage capacity and ports' infrastructure or equipment, or increase the number of operational stops. Consequently, socio-economic impacts will likely be introduced. Such impacts can include the increased users' risk perception leading to lower rates of moorings and turnover, increased costs of maintenance in nautical installations and equipment, increased costs for new investment and insurance, carbon tax effects on fossil fuel prices, less turnover from maritime transport activities and disruption costs.

Estimating the costs and effectiveness of adaptation measures depends on the location of the port and is often difficult to assess. In most cases, however, the most effective adaption measure would be to improve the flood resistance of transport infrastructure and increase the height of the ports (Yang *et al.*, 2018). Most of these impacts and their economic value will be discussed in the next chapters.

Tourism

Coastal and maritime tourism is the largest maritime activity in Europe and employs almost 3.2 million people, generating a total of €183 billion in gross value added. It represents over one third of the maritime economy. In islands, tourism is usually the main economic activity, not only in Europe but also around the world (Arabadzhyan *et al.,* 2020).

According to the 5th assessment report of the IPCC3, climate change is expected to "reshape" the tourism industry and will impact the geographical and seasonal distribution of tourists all over Europe (Scott *et al.*, 2008). In this research, it is assumed that the whole tourism activity of the islands is assigned to the coastal and maritime tourism sector (hereafter referred as "tourism"). It is fully justified because the vast majority of the tourist activities in islands are based on the infrastructures and the natural attractions that are distributed throughout the coastal and littoral areas, and all tourists visiting inland areas enjoy their coastal environments during the visit (going to beaches, consuming coastal-based food and/or undertaking outdoor activities). It is relatively easy to demonstrate that in almost all cases, the iconography and tourism image of the islands are related to the sea and the coastal resources (Arabadzhyan *et al.,* 2020), and that the main tourist motivations pull factors to visit islands rely on sea-based assets.

Thus, tourism as a demand-side phenomenon refers to the activities of visitors and their role in the acquisition of goods and services, usually related to coastal resources. It can also be viewed from the supply side, and tourism will then be understood as the set of productive activities catered mainly to visitors during their stay. Changes in the multiplicity of variables that constitute the climate of the islands are the consequence of global warming, in its turn powered by human-induced emissions of GHG. These changes happen in each island depending of the complex interactions between air masses speed, temperature, and humidity; circulation, temperature and acidity of the oceans; and the location, topography and bathymetry, vegetal covered and types of soil characterizing the islands. In addition, tourism long-term sustainability depends on the preservation and enhancement of its environment.

All biophysical changes are directly and indirectly affecting tourism, especially in destinations where nature is a key attractor for tourists. Alteration of natural resources through changes in average conditions (water temperature and quality, biodiversity, etc.) or occurrence of extreme events (forest fires, droughts) may affect tourist practices in rural and coastal environment such as walking, riding, hiking, swimming. These impacts can damage ecosystems, biodiversity and landscapes, as well as infrastructure and human wellbeing. They can also increase difficulties in risk management of these areas in order to provide a safe environment and affect more broadly the tourism businesses in long-term when alteration is sustained (marketing, investments in those locations).

Energy

There are more than 2,200 inhabited islands in the EU. Lately, they have come into the focus of the EU, which addresses energy questions as part of the 'Clean energy for all Europeans' package. The Clean energy for EU islands initiative provides a long-term framework to help islands generate their own sustainable, low-cost energy. This is particularly interesting, because many islands have vast amounts of renewable energy sources but rely on fossil fuel imports yet. These are relevant challenges regarding the energy transition in the EU, whose aim of net zero greenhouse gas emissions in 2050 should determine the future energy plans of the islands. Islands could provide showcases for successful 100% renewable energy supply.

However, how can the islands' energy supply be robust against climate change? And how will energy demand change in a world with a changing climate? In brief, which are the risks that climate change poses to the respective energy systems on European islands?

The National Hydropower Association (NHA) defines marine energy as electricity generation from marine kinetic energy, such as waves, tidal and ocean currents. Pisacane *et al.* (2018) add other marine energy sources like ocean thermal energy conversion (exploiting temperature differences between deep and surface ocean waters) and salinity gradient energy (harnessing the energy potential of differences in salt concentration in ocean and river waters). All these technologies are still in a development phase, and even if they reach the commercial phase in the future, it is not likely that they will generate a large share of the power. Therefore, the analysis of this book refers to the main renewable energy sources (RES), wind energy and solar photovoltaic (PV) energy, which are currently, and very likely in future, the backbone of the deployment of renewable energies, due to their technological maturity and low cost.

Not only onshore but also offshore wind energy is taken into account. The latter is a specific marine energy source which has distinct advantages like much higher productivity and less time variability than onshore wind energy, and does not require land space which is limited and costly in the islands. There are relevant obstacles for its deployment, like the deep bathymetry surrounding most of the islands, and the lower wind speeds over the Mediterranean in comparison to areas like the North Sea where offshore wind energy is being deployed rapidly. But recent technological advances in floating supports for the wind towers and cost reductions are opening this possibility, so that currently there are two commercial-scale projects respectively for Gran Canaria and Sicily.

Additionally, we consider also offshore PV energy. Despite some disadvantages that have to be overcome (corrosion problems due to salty water or the impact of waves), this application is receiving growing interest, as it offers an alternative option for renewable energy development in countries and islands with limited space for the installation of solar panels, and can show increased performance due to the cooling effect of water and wind on PV cells (Golroodbary and Sark, 2020). The installation of offshore floating PV panels has been already tested for one of the islands analysed (Malta; Grech *et al.*, 2016), and one offshore PV farm is already operating near the coast of the Netherlands (Gutiérez *et al.,* 2020), an area characterised by high waves. Offshore floating photovoltaics is being considered in future strategies and plans, like the recently published Roadmap for the Offshore Renewable Energy Strategy of the European Comission or the report of Monitor Deloitte and Endesa (2020) proposing a plan for the accelerated decarbonization of Canary and Balearic Islands.

Most RES depend on the climate, and therefore, climate change can have an impact of the resource amount. Additionally, wind and solar PV energy are not dispatchable, and its variability represents a challenge for its integration in the power system. This is a challenge that can be addressed through storage or backup plants (which can be itself renewable energy plants), through demand management, but also taking advantage of complementarity of PV and wind energy and its very different variable characteristics.

This approach is gaining attention from stakeholders in the islands, as demonstrated by the report by Monitor Deloitte and Endesa (2020), in which one of the key recommendations for achieving an accelerated zero carbon target in Balearic and Canary Islands by 2040 is the combination of solar PV and wind energy, with clearly higher shares of PV than of wind energy. Such a mix would reduce strongly the need for storage, due to the stability of solar PV production.

There are also challenges for the demand and transmission components of the energy systems of the islands due to climate change: changes in temperature leading to changing energy demand, changes in precipitation and evaporation creating risks for desalination, and extreme weather events (particularly extreme winds) challenging the distribution of the infrastructure. Next chapters will be dedicated to analyse the effects of climate change on the demand and supply sides of the energy system.

Aquaculture

In recent decades, the amount of farmed fish consumed by the world's human population has been constantly growing, from 14 million tonnes per year in the 80s and early 90s to over 82 million tonnes in 2018 (FAO 2020). The contribution of aquaculture to fish production has grown from 25.7% in 2000 to 46% in 2018. However, in Europe, the share of aquaculture in fish production is only 17% and the EU is the largest importing market (FAO 2020). When looking at finfish production in 2018, only 13.44% was produced in marine and coastal environments, while inland aquaculture, mostly freshwater, accounted for the highest contribution to farmed fish production (FAO 2020).

The Food and Agriculture Organization of the United Nations (FAO) highlighted that there is a growing need to transfer coastal aquaculture production systems further offshore. From the global perspective, this is due to the expected increase in human population and to the increasing problem of wild-caught seafood overfishing, as well as to the competition for access to land, clean water and sea space that can limit the availability of fish and fishery products for human consumption from inshore farms. As a matter of fact, due to the divergent spatial, economic and political interests among the many coastal stakeholders competing for marine space (e.g., to be granted access to fishing grounds, shipping routes, marine environment protection, touristic development of coastal areas, seabed extraction rights, marine renewables deployment opportunities), further development of aquaculture can only be achieved after accurate combined mapping of the biological production potential and of the constraints deriving from existing ocean uses and limitations (Oyinlola *et al.*, 2018), highlighting the crucial role that economic planning and governance play in shaping growth trajectories by harmonizing economic, environmental and social objectives.

In this context, offshore aquaculture represents a novel perspective as to governance issues, by shifting the competition for marine space from the historically well-rooted social networks with traditional use patterns to a limited number of large, often international operating companies, with limited social networks and engagement with each other. Offshore aquaculture may also reduce the environmental impacts of nutrient release in correspondence of farms, and allow expansion of the operations to enable large-scale growth also in the connected sectors, provided suitable farming practices are adopted (Abhinav *et al.*, 2020).

For these reasons, the growing interest to move large scale aquaculture operations further out into the sea has transformed the sector into an innovative research field, which requires advanced solutions spanning a wide range of technical, social and managerial competences (Buck and Langan, 2017). "Offshore" aquaculture depends on a variety of factors, both topographical (e.g., distance from shore and depth) and operational (e.g., accessibility of farms). A simplified definition was proposed by Drumm (2010), who identified it as being exposed to wind and wave action, and requiring equipment and servicing vessels to survive and operate in severe sea conditions, while the distance from a shore base or a harbour is not always a distinctive factor.

However, such classification criteria can only give a preliminary idea of the farming conditions, and specific individual situations should always be considered as to both prevailing local environmental conditions at the sites and administrative constraints. As regards this last aspect, offshore locations might in fact fall within internal waters in some countries with extensive archipelagos and in international waters for other countries.The possibility of moving farms farther offshore clearly relies on: a) the recent design of more robust culture technologies based on substantial advances in numerical and physical modelling of cages and longlines and of their optimal arrangement (Drimer, 2019), b) innovative strategies with respect to those adopted for inshore farming, such as Integrated Multi-Trophic Aquaculture[6] (IMTA) systems (Buck *et al.*, 2018), and c) the development of novel culture systems that can be submerged to avoid the winds and waves characteristic of offshore areas. A number of such technologies now exist at the commercial stage of development, consisting of either rigid or tensile structures, that remain at the surface in normal conditions but can be submerged upon early warning, before a storm reaches the farm site (Sturrock *et al.*, 2008). Submersible systems offer the additional advantages of avoiding harmful oxygen-depleting algal blooms and of enabling the re-positioning of cages in correspondence of optimal currents and/or temperatures to improve fish farming conditions, optimize growth and avoid thermal stress, at the same time reducing the exposure to parasites and anthropogenic pollution (Buck and Langan, 2017). In addition, intelligent monitoring and control technologies for the optimization of operations at sea are constantly being developed, to increase yield and achieve high efficiency and safety of farming (Wei *et al.*, 2020).

Local communities would naturally act as nodes for farm operation and maintenance, thus benefiting from the potential creation of additional jobs, income protection through diversification, and access to new markets, with a consequent increase in the social acceptance of offshore development (Buck *et al.*, 2018). Nevertheless, local and regional planning is crucial to correctly assess how such developments are liable to affect the interlinked social and natural systems, and thus, to avoid negative impacts.

Climate change adaptation represents an additional constraint on the future status and development of this sector, which will possibly imply additional costs for existing enterprises and determine the feasibility or the necessity of moving the activities in more suitable environmental conditions. A thorough assessment should obviously rely on detailed geographic information systems, detailed monitoring and mapping of the marine environment and high-resolution circulation models covering a wide range of scales and expanding from the open sea to the coast, as well as on spatial planning tools to support the ecosystem approach to aquaculture. That is to say, a complete and costly set of management tools should be developed and tuned to specific situations and needs, in order to support aquaculture planning at local levels (Macias *et al.*, 2019).

In this book, an overall open-sea assessment of the expected climate change impact on aquaculture is conducted, setting a framework for further and more detailed analyses and easing the early elicitation of the trade-offs this sector is liable to deal with. It provides a first evaluation of their degree of exposure and vulnerability, and a preliminary assessment of the local impacts, either negative or positive, of climate change on this industry.

The Mediterranean Basin

Following the global trend, in the Mediterranean countries, aquaculture has grown to become a crucial contributor to regional fish production, exploiting a wide variety of environments and farming technologies. Such development benefited from the substantial improvements in floating cage technology, which allowed aquaculture to progressively move further into the open sea (FAO, 2017), thus minimizing conflicts of use in an overexploited maritime space, and better meeting environmental constraints.

This positive trend is expected to consolidate in future years as a result of aquaculture development plans in the region, posing severe constraints on the management of maritime space and demanding accurate planning in order to mitigate the increasing pressure on coastal zones. Strategies must be designed to avoid that the availability of suitable areas for marine aquaculture turns into a bottleneck for any further development of the sector, given the harsh competition for sea space among a variety of well-established blue economy sectors and the extreme vulnerability of the Mediterranean area to environmental stresses (Macias *et al.*, 2019).

Based on biological considerations only, the Mediterranean basin can be classified as a suitable area for offshore aquaculture development (Oyinlola *et al.*, 2018), offering the advantages of sustained currents (10-100 cm/s) and temperature and chlorophyll-a threshold ranges that allow the farming of autochthonous species, as well as the opportunity of placing installations within cost-effective distance from the coastline (McDaid Kapetsky *et al.*, 2013).

However, the global race to design technologies for offshore aquaculture in much more extreme conditions than those represented by the comparatively mild Mediterranean climate, as well as the development of marine renewables in the region that would enable the co-location of multi-function platforms (Pisacane *et al.*, 2018), now make the offshore option more appealing for the sustainable future development of the sector in the Mediterranean Sea, which is reported to be world's most overfished basin (FAO, 2018).

In the future, resorting to offshore aquaculture might also help counteract the expected warming due to climate change, and allow better environmental conditions for fish farming in colder waters and sustained currents. At present, it would help preserve the Mediterranean seagrass meadows which provide important marine ecosystem services and constitute an invaluable heritage as to both ecology and biodiversity. Seagrass regression may be due to natural processes, natural disturbances and/or anthropogenic pressures, including climate change. Human-induced losses of Po*seidonia oceanica* have been related to coastal development, pollution, trawling, fish farming, moorings, dredging, dumping and introduced species, although accurate data are generally very local and are lacking at basin scale (Abhinav *et al.*, 2020). However, the moving of aquaculture from costal area above seagrass beds to the deeper waters around Cyprus, away from the meadows, constitutes a documented case of meadow recovery, all the more important as these areas are characterized by thermal conditions that are at the upper limits for the species (Kletou *et al.*, 2018). The design of suitable mooring systems clearly represents a prerequisite for such option, in this as in other Mediterranean environments (Vassiliou *et al.*, 2012).

In 2017, the General Fisheries Commission for the Mediterranean adopted the strategy for the sustainable development of Mediterranean and Black Sea aquaculture in the form of Resolution GFCM/41/2017/1, envisaging a future where production in this region will be globally competitive, sustainable, profitable and equitable. The Mediterranean and Black Sea coastal countries will be supported in formulating harmonized aquaculture activities and action plans, considering the environmental and socioeconomic priorities at all the relevant spatial scales, from the regional, to the national and local, in conformity with existing national and supranational strategies and legal requirements.

The European Mediterranean islands need their touristic vocation to be harmonized with the development of sustained industrial activities, reconciliating the competitive uses of marine space across the tourism industry, maritime transport infrastructures, the emerging opportunities offered by marine renewables, and the exploitation of fisheries and aquaculture. Offshore aquaculture can disclose significant opportunities for sustainable food production, for both the local and the continental markets, and for the development of insular communities, especially in small islands where the availability of nearshore space is limited.

The Caribbean Islands

The aquaculture industry has so far relied for its development on government participation in small- and mediumscale enterprises, while global economic trends now oblige the sector to upscale and meet the standards and conditions of international trade, combining social equity, environmental sustainability and competitiveness through product diversification (Abhinav *et al.*, 2020).

The Caribbean has a large unexploited potential for deep-sea fish farming, which could produce over 34 million metric tons of seafood per year. Offshore mariculture is indicated as a valuable option for the economic development of the region, increasing seafood production at the same time as reducing the over-exploitation of wild fisheries and the pressure on coastal ecosystems (Thomas *et al.*, 2019). Technological development has now loosened this latter constraint, while the growing concern for marine habitat protection has progressively augmented the appeal of offshore farming, as it offers the opportunity of avoiding conflicts with other sea uses and helping preserve sensitive coastal habitats (coral reefs and seagrass meadows) in protected areas.

The Caribbean also shares with the Mediterranean the positive condition of belonging to an Exclusive Economic Zone (McDaid Kapetsky *et al.*, 2013). Nevertheless, any further development of the aquaculture industry will by necessity depend on the successful application of efficient technologies, innovation, modernization and reconversion processes, in order to increase the production of high-quality seafood and obtain an adequate return on investment. The crucial role of research and administrators will be to guarantee the conservation of the local natural marine habitats, the constant improvement in farming technologies, and the sustained capacity of attracting foreign investments in the context of the global trends in marketing and economics by fully assuming the required regulatory and monitoring responsibilities. To this end, the development of information systems and suitable mid- and long-term planning instruments in support of farmers and investors is recommended, including climate analyses aimed at characterizing the potential threats of warmer sea waters and increased frequency of occurrence of tropical cyclones (Abhinav *et al.*, 2020).

Macaronesia

The Islands jointly referred to as Macaronesia (Azores, Madeira and Canaries) are oceanic islands that face diverse development challanges, mainly due to their distance from the mainland and limited land space, and where standardized mainland-based strategies cannot be directly implemented, as the complexity of the local context needs to be accounted for (Chapman, 2011). They usually experience more severe environmental constraints, exhibiting more variable and extreme climatic conditions and peculiar biogeographical attributes (e.g., higher waves, stronger currents, stronger winds, less nutrient input from rivers, narrow continental shelves, lower primary production). Moreover, their wild species often present distinctive evolutionary features, such as a high level of endemism and speciation, and unique biodiversity (Whittaker *et al.*, 2008).

As a result of the technological developments enabling high-sea farming, aquaculture can now offer a valuable oppportunity for the socioeconomic development of such remote areas, helping avoid the over-exploitation of local fish stocks and allowing the diversification of products. Indeed, the first offshore fish farms installed in Madeira in the mid-1990s, as an initiative of the Madeira Fisheries Department, demonstrated the technical and commercial viability of aquaculture in the open and deep seas of the region, and served as a test case for other islands. The main economic constraint on the business proved to be that typical of small island industries far from the continent, namely the sustainability of the ratio between importation of production supplies (fingerlings, feeds, chemicals) and sales of end products. Production and maintainance costs evidently increase as a function of potential transport disruption, lock-down of farming operations, damages to cages and nets and loss of fish stock due to bad weather. Two additional costly logistical constraints are represented by the lack of local services (cranes, repairs, etc.) and of space for land bases near service piers. Some of the named obstacles had positive institutional responses, from the POSEI EU Programme for ultra-peripheral regions to the development of extensive government services and R&D in support of farmers (Aguilar-Manjarrez *et al.*, 2017).

The growth of the sector, however, must from now on also recognize as a priority the conservation of the natural patrimony, and align with effective marine protection plans. Any effective strategy to accelerate Blue Growth must necessarily preserve the significant ecosystem services offered by the several Marine Proteced Areas (MPAs), as well as incentivate the sustainable management of the tourism fluxes attracted by the region’s natural beauty (Aguilar-Manjarrez *et al.*, 2017).

Why a Common Framework for the Blue Growth on Islands?

Europe’s islands face common climate risks as recognised in the New EU Strategy on Adaptation to Climate Change, (Brussels, 24.2.2021 COM (2021) 82 final): “Although the local specificity of adaptation often makes comparison difficult, it can be made for areas crossing several borders with common climate risks”, which includes, besides river basins and mountainous areas, “the islands, or the outermost regions (which are particularly vulnerable to climate change).”

The context and characteristics of the islands makes it essential to define a common framework for the governance of the blue economy that reflects the integration in EU policy. For islands, it is also essential to define climate change pathways that capture the future needs funding allocation for adaptation and the risk priorities associated, particularly in vulnerable communities and territories. Risk-based adaptation policy pathway design, based on climate projections, to promote resilience and minimize future risks and damages will enable an efficient use of resources and taking advantage of opportunities related with climate change.

Mainstreaming of climate change (adaptation and disaster risk reduction) policy in the economic sectors is relevant for the development of successful and appropriate options and measures. The climate change policy in the context of the blue economy sectors will facilitate climate proofing of blue economy sectors and support the development of resilient and adaptive infrastructure to future climate.

In sum, Blue Growth is expected to thrive in a scenario of sustainable growth particularly through sustainable maritime innovations. Thus, it is crucial to build a common language for islands to work on the enhancement of long-term conservation of coastal and marine resources. Harnessing the richness of the ocean for economic activities requires a systematic Blue Growth approach. In other words, the sustainability of the economic activities in the maritime environment can be significantly improved through promoting greater sustainable management of marine resources, crosssectoral planning and plausible accounting systems of impacts of the sectoral activities.

Climate Change Impact Chains: A Common Language

The concept of Impact Chain (IC) was introduced by Isoard *et al.* (2008) and Schneiderbauer *et al.* (2013), then 'catalyzed' by the German cooperation (GIZ) in the Vulnerability Sourcebook (Fritzsche *et al.*, 2014) and since then widely used as a climate risk assessment method at the global scale (UNDP, World Bank, Horizon 2020, etc.), as well as at local, regional or national level.

Under this approach, risk is defined as 'the potential, when the outcome is uncertain, for adverse consequences on lives, livelihoods, health, ecosystems and species, economic, social and cultural assets, services (including environmental services) and infrastructure' (IPCC, 2014a, p. 127). Thus, risk assessment concerns the interaction of climatic, environmental and human factors that can lead to impacts and disasters, the options for managing the underlying risks, and the important role that non-climatic factors play in determining (Fritzsche *et al.*, 2014).

Impact Chains (ICs) can be both a technical tool integrating quantitative and qualitative results from different disciplines, and a participatory tool, allowing a better understanding and dialogue with communities, policy makers and stakeholders. ICs have the capacity to be cross sectoral and cross scales and allow to aggregate or downscale risks and compare sectors. This methodology has been employed to analyze climate-related risks for agriculture, food production and consumption, terrestrial and marine biodiversity and represents the main application to support the design of disaster risk management and adaptation strategies in urban and coastal cities (Abadie, 2018).

It is considered the most appropriate appraisal method for understanding and communicating climate change effects on any sector, thus, facilitating policy design. The IC looks like a diagram (Schneiderbauer *et al.*, 2013), which summarizes the relationships between different climate shocks, ecosystem services and economic activities under study, taking into account exposure (to climate parameters), sensitivity (related to physical and socio-economic features of the destination), and adaptive capacity. The components of the IC can be defined as follows:

Hazard is the potential occurrence of a climate-related physical event or trend, or its physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources.

Exposure is the presence of people, livelihoods, species, ecosystems, environmental functions, services, infrastructures, economic, social, or cultural assets in places and settings that could be adversely affected. The degree of exposure can be expressed by absolute numbers, densities, or proportions of the elements at risk (e.g., population density in an area affected by drought).

Vulnerability is the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (Abadie, 2018). Sensitivity may include physical attributes of a system (e.g., building material of houses, type of soil in agriculture fields), social, economic, and cultural attributes (e.g., age distribution, income distribution).

Adaptive capacity refers to the ability of societies and communities to prepare for and respond to current and future climate impacts.

Risk is the potential climate-related consequence (climate impact) for something of socio-economical value (assets, people, ecosystem, culture, etc.).

Impacts are the effects on natural and human systems, on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate change or hazardous climate events occurring within a specific time period, given the level of vulnerability of an exposed society or system (see **Figure 2**).

As regard the study of the impacts of climate change on 12 European Islands and Outermost Regions, we propose the Impact Chains conceptual architecture. In order to define the ICs to be studied, an expert assisted process was implemented. Twelve focus groups were organized, which saw the participation of more than one hundred climatologists, environmental economists, geographers, high-level policy makers and practitioners of the islands under study. The final set of IC aimed at defining measurable risks of common concern for all European islands, and at the same time, that can easily be applied to assess and quantify CC impacts on the four blue economy sectors on many other coastal areas.

The ICs in each sector were defined as follows:

Tourism

1. Loss of attractiveness due to marine habitat degradation.
2. Loss of attractiveness due to beach availability reduction.
3. Loss of attractiveness due to increased danger of forest fires in tourism areas.
4. Loss of competitiveness due to a decrease in thermal comfort.
5. Increase of health issues due to emergent diseases.
6. Loss of tourist experience value in the destination due to the change in the quality of infrastructure and facilities.
7. Increase of damages to infrastructures and facilities (accommodation, promenades, water treatment system, etc.).
8. Decrease of available domestic water for the tourism industry.
9. Loss of attractiveness due to loss of cultural heritage (monuments, gastronomy, etc.).

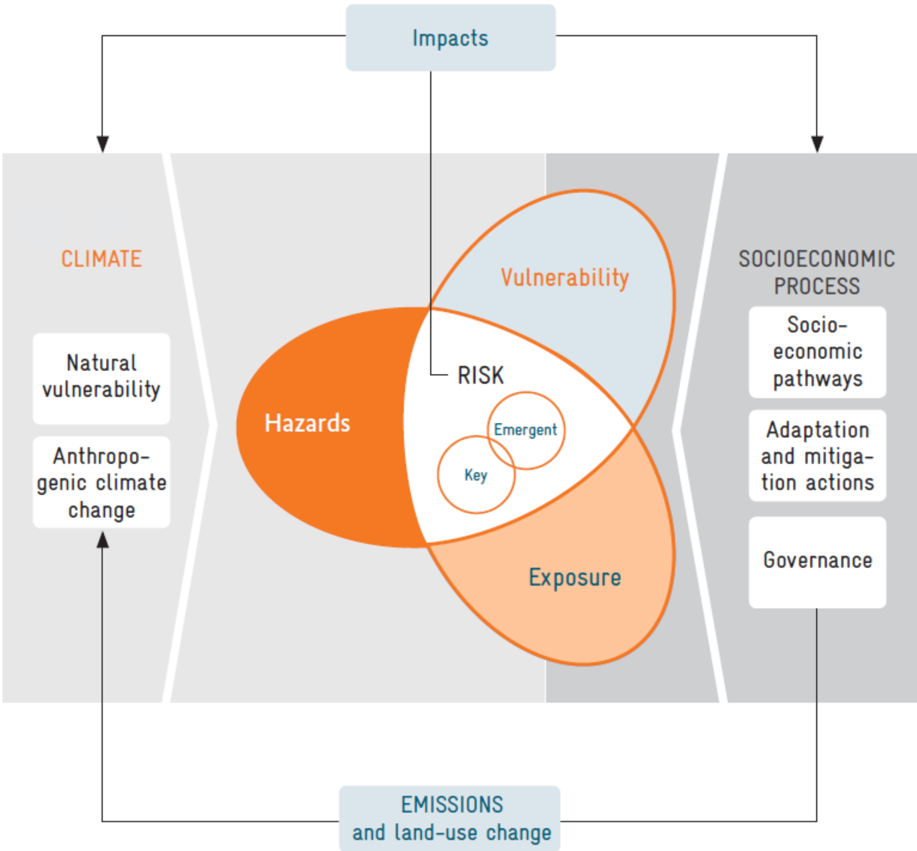


Figure 2. The concept of Impact Chain (IC).
Source: Glossary of the IPCC Fifth and Fourth Assessment Report.

Aquaculture

9. Decrease in production due to an increase in surface water temperature.
10. Increased fragility of the aquaculture activity due to increase of extreme weather.

Energy

11. Risk of increased energy demand due to increased cooling demand.
12. Risk of increased energy demand due to increased desalination/puping needs.

Maritime Transport

13. Risk of isolation due to transport disruption.

Appendices A to D show the graphic representation of the thirteen ICs under study. Following this framework, the study of the full chain of interconnections from hazards to physical and economic impacts is ensured. Thus, the research in each island was conducted with the following sequence:

- The projections of hazard indicators of relevance per each sector. The climate models were run for two scenarios RCP2.6 (low emission scenario) and RCP8.5 (high emission scenario) and for different horizon times namely: a reference period (1965-2005), mid-century (2046-2065) and end of century (2081-2100). Results are presented in form of graphs and maps.
- An iterative risk assessment, aiming not only to evaluate the risk, but also to monitor the risk components (vulnerability, exposure) evolve with time and respond to human interventions. This analysis was undertaken in a comparative way and through the use of different methodologies that are explained in the Appendices E to J.
- The potential economic impacts on the four blue economy sectors, considering specific hazards and risks. Different methodologies were used for each sector, including

non-market evaluation of adaptation policies (tourism sector).

- The socio-economic implications for the islands' systems by the application of general equilibrium and macro-econometric models. Changes in mean temperature, sea level and precipitation rates have been used as input to assess the effects on 14 sectors of economic activity, GDP, consumption, investments and employment.
- Propose alternative adaptation pathways for the islands that are framed by the socio-economic conditions and the scenario of CC in each island, as well as specific limits and obstacles that constrain their avenue to be more resilient territories (see **Figure 3**).

Finally, it is important to point out that it was not possible to study all the risks and components in each island, given the lack of reliable data and information. Moreover, not all sectors were analysed in some islands, as their economic relevance was not significant. Thus, next chapters present a very well personalized research outcomes according to priority risks, data availability and the economic relevance of the blue economy sectors in each island.

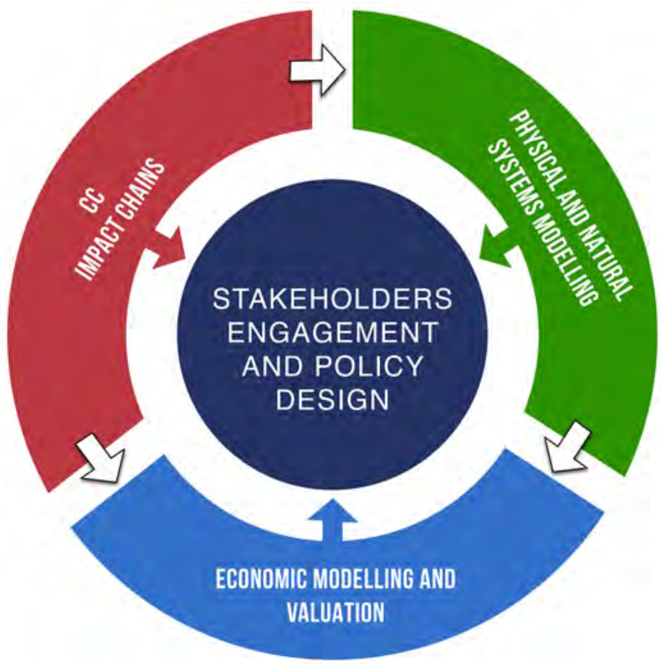


Figure 3. Conceptual and methodological vision.

Chapter 1

Azores (Portugal)

SOCLIMPACT

This project has received funding from
the European Union's Horizon 2020 research
and innovation programme under
Grant Agreement No 776661

CONTENTS

The Azores at a Glance

The nine islands of the Archipelago of the Azores are all of volcanic origin and are located in the middle of the North Atlantic, dispersed along a 600 km long stretch from Santa Maria to Corvo and approximately between 37° and 40° north latitude and 25° and 31° west longitude. Some 246,772 people live (data from 2011) in this island territory of 2,325 km^2, which is at a distance of 1,600 km from the European continent and 2,454 km from the North American continent (Canada). The population distribution is around half for the main island São Miguel, one quarter for Terceira island and the remaining islands account for another quarter.

- **Tourism**

  The coastal recreational and leisure activities are one of the main tourist attractions in the region. These include activities such as recreational boating, and maritime-tourist activities (e.g., cruise tourism, diving, whale and dolphin watching, swimming with dolphins, sport fishing) and nature tourism (e.g., hiking and sightseeing). A growing activity is also tourist real estate, especially on the coast, which results in the construction of various support infrastructures along the coastline.

- **Energy**

  In 2019, the annual consumption was around 743 GWh. Production was 38.3% from renewables and local resources. The Islands are all non-connected in between and are dependent on fossil thermal generation to ensure energy quality and face a challenge to add more renewable energy. Some islands have well established geothermal energy running (São Miguel and Terceira). They all face and cope with harsh climatic conditions and are challenged with high winds (i.e., 213 km/h) as well as heavy precipitation with the risk of floods and landslides. Climate change will aggravate these risks and create new ones, challenging the region.

- **Aquaculture**

  The aquaculture sector in the Azores aims to contribute to the creation of business niches associated with aquaculture products, providing opportunities for social development and employment and, at the same time, increasing regional productivity without increasing the extractive pressure on fishery resources. The sector is still developing in the region, and conditions are still being defined for the exercise of the activity on an experimental or scientific basis.

- **Maritime Transport**

  The maritime-port sector is responsible for around 70% of international trade and plays a fundamental role in the development of the region. The importance of maritime transport, namely cargo, led to the development of port infrastructures, which assume on all islands a fundamental role in the flow of goods in and out. This is the main means of transporting goods, both for connections abroad, namely to Madeira and the Portuguese mainland, as well as inter-island connections. Passenger shipping works all year round in the central group, and service is extended in the summer months to all other islands.

1.1. Current Climate and Risks

The Azores islands have an autonomous adaptive capacity that was driven by centuries of exposure to harsh conditions presented by the North Atlantic sea. All aspects of life and infrastructure are designed to withstand stresses that are not applicable to the mainland. For instance, storm Hercules brought high winds with gusts reaching 213 km/h on the Flores island in February 2014, resulting in minor damages to the energy grid.

The same event would most likely cause havoc in Portuguese mainland, as it was in the case of storm Leslie, where wind gusts of 176 km/h were recorded and 200 high and medium voltage transmission towers were downed. This leads to power shortages in the energy service which in some instances took weeks to recover. Also, there are significant differences regarding systems' resilience inside the region and in different Islands. For example, the occidental islands can resist extreme winds that can be problematic in the central islands (see **Figure 1.1**).

CURRENT CLIMATE-RELATED RISKS

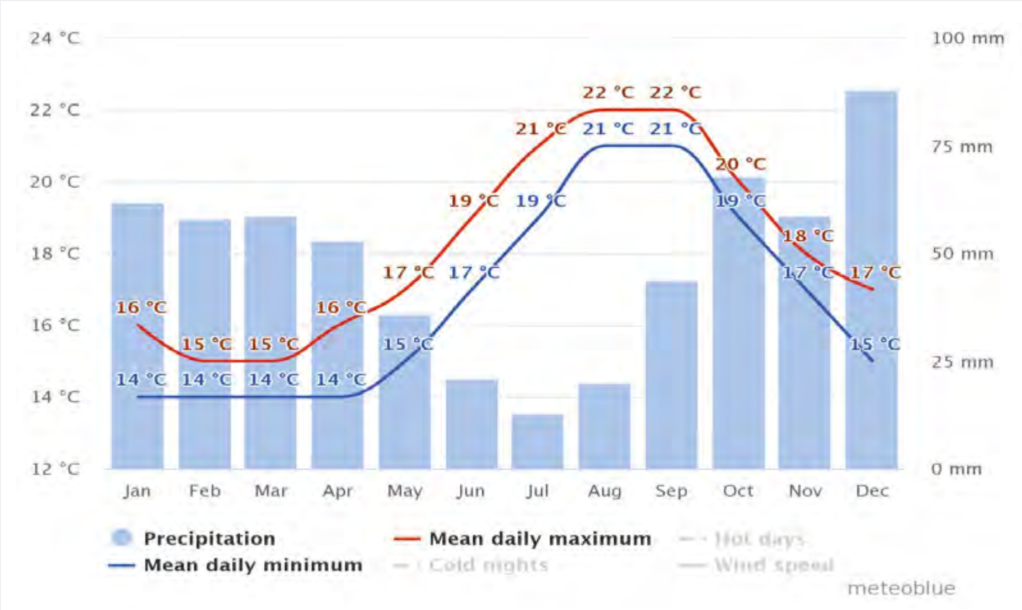
- Coastal flood High
- Cyclone High

SIGNIFICANT CLIMATE EVENTS

- Floods (2009, 2018, 2019)
- Storms (2012, 2018)
- Landslide (2010, 2012, 2013)

CLIMATE CHARACTERISTICS (37.74°N 25.67°W, 10m asl)

Average temperature and precipitation



Cloudy, sunny and precipitation

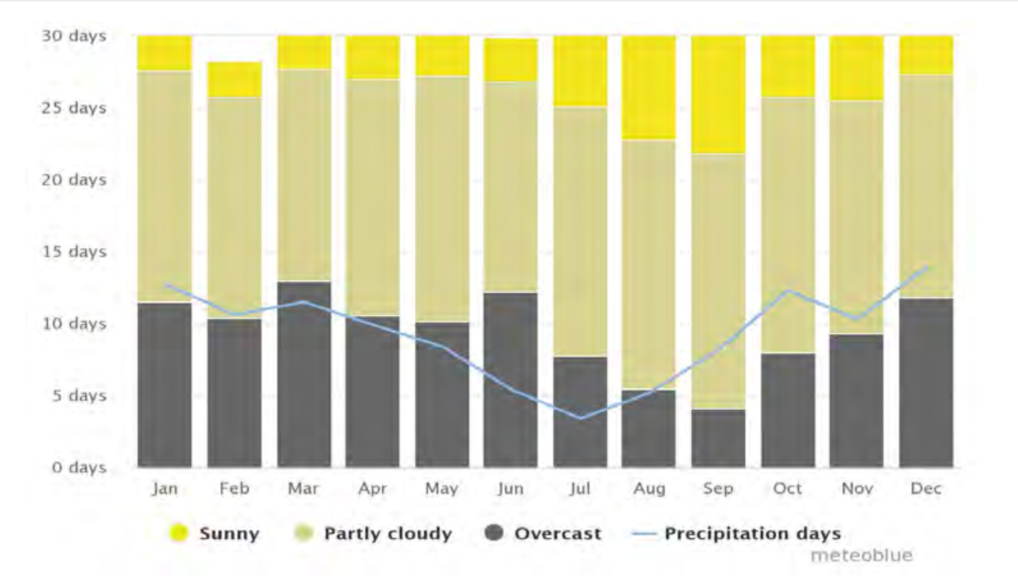
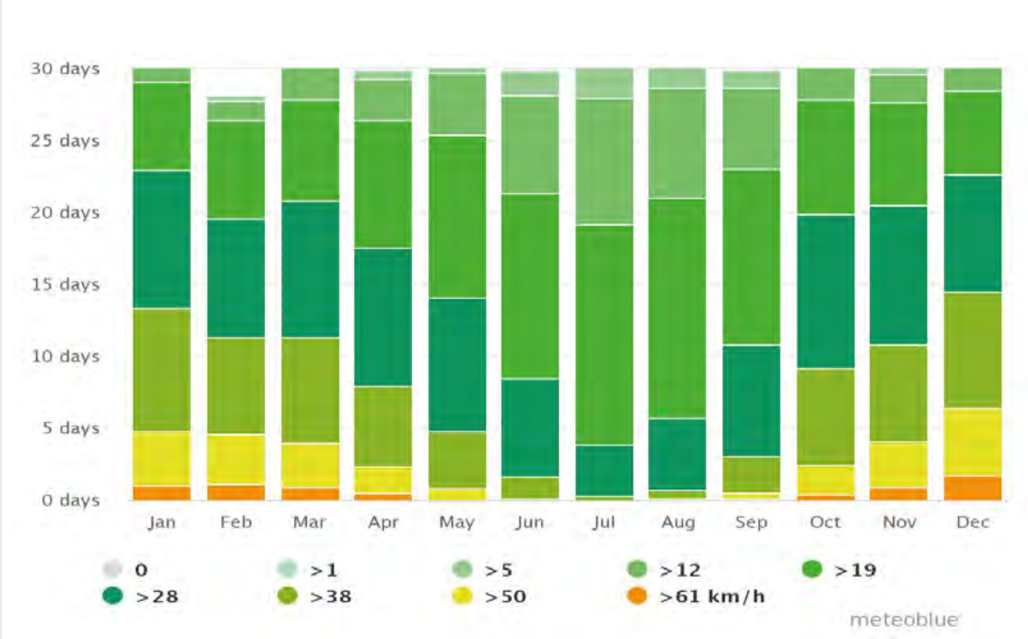


Figure 1.1. Climate factsheet.

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System). ***(Continued on the next page)***

Wind speed



Wind rose

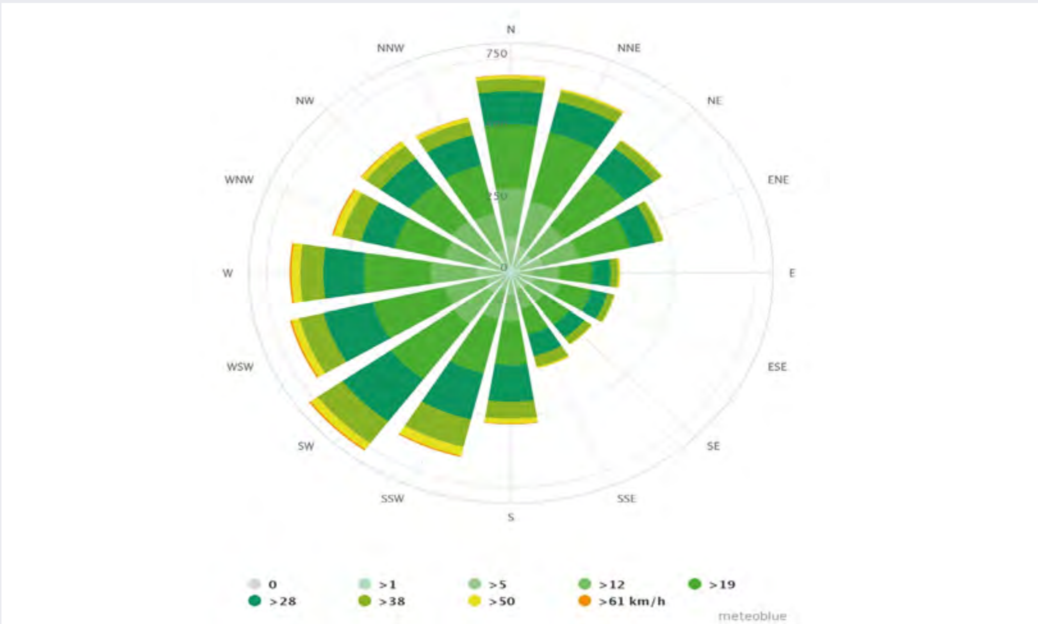


Figure 1.1 (Cont.). Climate factsheet.

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System).

1.2. Macroeconomic Projections

According to reference projections, the Azores continue to grow on average with a 1.5% yearly rate throughout the 2015-2100 period. The main driver of growth is private consumption with an average yearly growth rate of 1.8% over the whole projection period (see **Table 1.1**). While the respective GDP-shares of trade and investments remain relatively stable over the projections period, the GDP-shares of public consumption are projected to decrease over time (see **Figure 1.2**).

1.2.1. The Sectoral Projections

The economy of the Azores remains a service-led economy throughout the 2015-2100 period with an increasing contribution of other market services, other transport services, electricity, water and accommodation and food services.

The aggregated gross value-added shares of agriculture, fishery, manufacturing and consumer goods sectors are projected to decline slightly from above 15% in 2015 to about 13% until 2100. The respective shares of electricity and water services are projected to increase only slightly until 2100. Construction activities contribute between 7% and 8% to total gross value added throughout the projection period.

Total tourism activities are projected to increase their respective gross value-added shares. Starting from more than 8% in 2015, this share is projected to increase to 9.3% until 2100[1] (see **Figure 1.3** and **Table 1.2**).

Table 1.1. Azores GDP and GDP components yearly growth rates in 2020-2100.

	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
GDP	2.9%	1.4%	1.3%	1.2%	1.1%	1.0%	1.0%	1.6%	1.6%	1.6%
Private consumption	4.5%	1.8%	1.7%	1.5%	1.4%	1.3%	1.2%	1.7%	1.7%	1.7%
Public consumption	-0.1%	0.0%	0.0%	-0.1%	-0.2%	-0.3%	-0.4%	1.7%	1.7%	1.7%
Investments	2.8%	1.8%	1.6%	1.5%	1.4%	1.3%	1.2%	1.0%	1.0%	1.0%
Trade	2.8%	1.8%	1.6%	1.5%	1.4%	1.3%	1.2%	1.5%	1.5%	1.4%

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

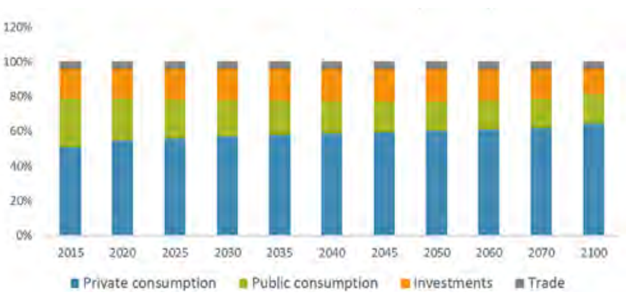


Figure 1.2. Macroeconomic components as a% share of GDP for Azores in 2015-2100.

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

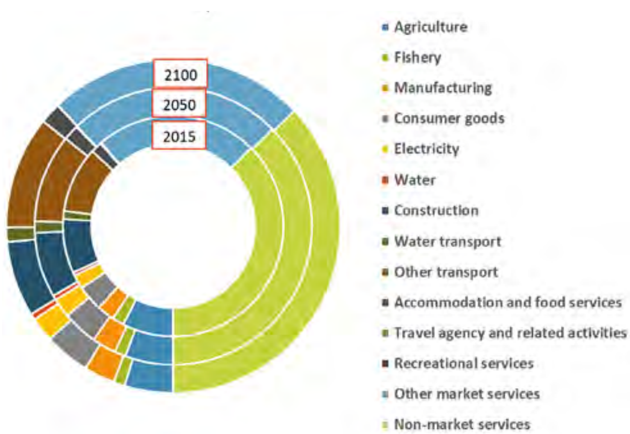


Figure 1.3. Sectoral value added as a% share to total GVA for Azores in 2015, 2050 and 2100.

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

1 The share of tourism in GDP is calculated via the tourism satellite account (TSA) matrices of 2015, assuming that the same shares that indicate the contribution of tourism to the productions of tourism-related sectors (such as the accommodation and food services, transport services, travel agency and related activities, cultural and recreational activities) remain throughout the 2015-2100 period. Please, see SOCLIMPACT Deliverable Report - D6.2 for the complete database of the estimated TSAs.

Table 1.2. Sectoral contribution as a% share of total gross value added for Azores in 2015-2100.

GVA% shares	2015	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
Agriculture	7.5%	6.6%	6.3%	6.1%	6.0%	5.8%	5.7%	5.6%	5.4%	5.2%	4.7%
Fishery	1.7%	1.5%	1.5%	1.4%	1.4%	1.4%	1.3%	1.3%	1.3%	1.2%	1.1%
Manufacturing	2.6%	2.6%	2.7%	2.7%	2.7%	2.8%	2.8%	2.8%	2.8%	2.9%	3.0%
Consumer goods	3.8%	3.9%	3.9%	4.0%	4.0%	4.1%	4.1%	4.1%	4.2%	4.2%	4.4%
Electricity	2.0%	2.1%	2.1%	2.2%	2.2%	2.2%	2.2%	2.2%	2.3%	2.3%	2.4%
Water	0.5%	0.5%	0.5%	0.5%	0.5%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%
Construction	7.9%	7.6%	7.5%	7.5%	7.5%	7.5%	7.5%	7.6%	7.6%	7.6%	7.3%
Water transport	1.2%	1.2%	1.2%	1.2%	1.3%	1.3%	1.3%	1.3%	1.3%	1.3%	1.4%
Other transport	9.7%	9.8%	9.9%	10.1%	10.2%	10.2%	10.3%	10.3%	10.5%	10.6%	10.9%
Accommodation and food services	1.6%	1.6%	1.7%	1.7%	1.7%	1.8%	1.8%	1.8%	1.8%	1.9%	2.0%
Travel agency and related activities	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%
Recreational services	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Other market services	23.8%	24.8%	24.9%	24.9%	24.9%	24.9%	24.9%	24.9%	24.9%	25.0%	25.0%
Non-market services	37.5%	37.6%	37.5%	37.5%	37.5%	37.4%	37.4%	37.3%	37.3%	37.2%	37.1%

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

1.2.2. Employment

The service-led economic growth brings positive effects to the labour market with unemployment projected to more or less half in the long run. The contribution of each sector to total employment depends on the labour intensity of the sector. The biggest employing sectors are non-market and other market services. Construction as well as the consumer goods industries, other transport and accommodation and food services do also still provide significant employment contributions in 2100.

Tourism is the largest employer of the Blue Growth sectors under analysis, particularly due to the high labour intensity of accommodation and food services. The fisheries sector is projected to undergo a slight decline in economy-wide employment shares from around 2% to 1.5% in 2100. Electricity and water transport services feature more or less stable aggregated employment shares throughout the projection period. However, none of these sectors is projected to contribute more than 1% to total employment in 2100 (see **Table 1.3** and **Figure 1.4**).

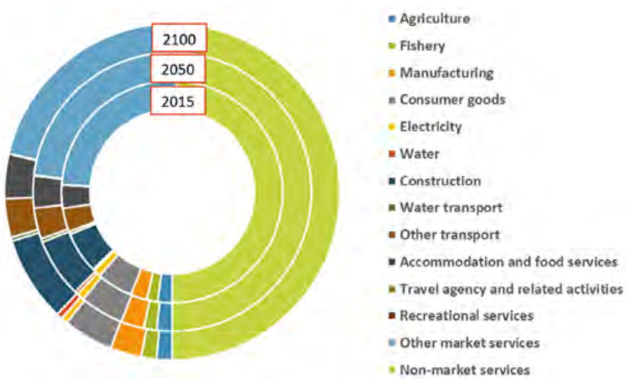


Figure 1.4. Sectoral employment as a% share of total for Azores in 2015, 2050, 2100.

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

Table 1.3. Unemployment rate for Azores in 2015-2100.

	2015	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
Unemployment rate	12.8%	11.3%	10.1%	9.1%	8.2%	8.0%	7.7%	7.3%	6.7%	6.2%	5.6%

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

1.3. Climate Change Outlook

Climate hazards indicators represent the entry point to understand the climate change exposure of the blue economy sectors. The indicators have generally been computed for two scenarios, RCP2.6 (ambitious mitigation scenario) and RCP8.5 (business as usual) and for different horizon times, namely: a reference period (1965-2005), mid-century (2046-2065) and end of century (2081-2100). The main source of climate projections (future climate) for the Azores Islands is MENA-CORDEX ensemble, even if other model sources were applied when required, depending on available scales. Results are presented in form of maps, tables or graphs and only when the information shows an interesting outcome.

As to its reliability, it is important to note that Atlantic islands (Azores, Madeira, Canaries and West Indies) lie in very critical areas where global models might be inaccurate in predicting the large scale patterns (regional models are not available), and resolution is so coarse that in fact many islands don't even exist in model orography. This acknowledged, this is the only information we can provide, and at least future tendencies can be inferred. The new CMIP6 simulations might shed more light on these issues, but we can only suggest that results should be updated as they become available.

The same partly holds for the wave simulations: local resolution has been significantly increased in the dedicated new simulations of this project, performed by the partner ENEA (up to 0.05°), but the forcing wind field is still derived from the coarse global models. Stakeholders should be made aware that uncertainty is an inherent characteristic of climate data, and that any future planning must cope with it. Climatologists can only highlight potential threats and constraints, they cannot predict the future and pave the way to solutions. Conveying this piece of information is one of the most critical points of climate-change-related information.

1.3.1. Tourism

1.3.1.1. Beach flooding and related losses

One of the consequences of an increase in the mean sea level will be the flooding of coastal areas. This includes sand beaches, which are the main asset for tourism activities in most of the European islands. Therefore, estimating the potential risk of beach loss due to climate change is of paramount importance for the economy of those islands. Under mean conditions, we find that, at the end of the century the total beach surface loss ranges from ~85% under scenario RCP2.6 to ~99% under scenario RCP8.5. Therefore, beaches could disappear in the Azores islands (see **Figure 1.5**).

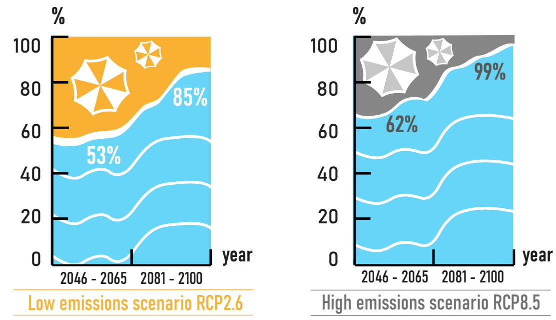


Figure 1.5. Beach reduction% (scaling approximation).
Source: SOCLIMPACT Project deliverable [*D4.4d Report*] *on the evolution of beaches.*

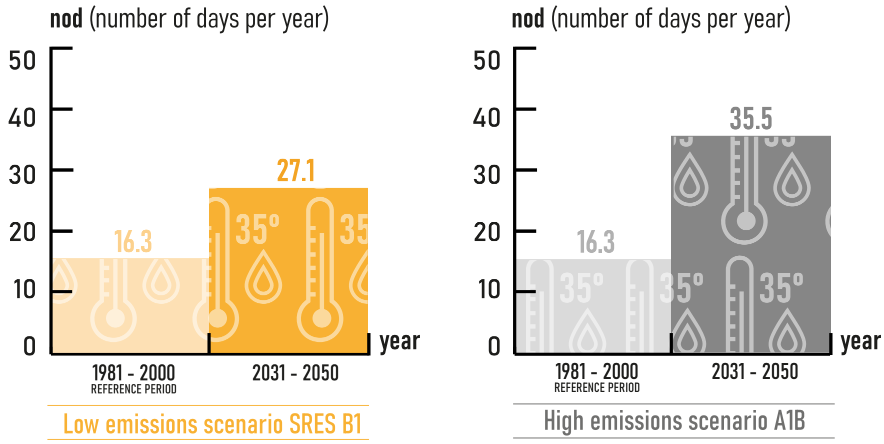
1.3.1.2. Humidity Index

For the assessment of climate hazard on heat related impacts of climate change on human health, the humidity index (Humidex) (Masterton and Richardson, 1979) has been used. Humidex value is an equivalent temperature, which expresses the temperature perceived by people (the one that the human body would feel), given the actual air temperature and relative humidity. As a more representative indicator for the assessment of inhabitants' and tourists' thermal comfort, the Number of Days with Humidex greater than 35°C was selected. From the above classification, a day with Humidex above 35°C describes conditions from discomfort to imminent danger for humans.

For the Azores, which are not included or are included marginally in the EURO and MENA-CORDEX domains, the ESCENA Project model runs (Jiménez-Guerrero *et al.,* 2013) were employed, which have been produced under the AR4 IPCC scenarios with 25 km spatial resolution. Here, Special Report on Emissions Scenarios (SRES) B1 and A1B scenarios are selected, considered to be closer to RCP2.6 and RCP8.5, respectively. The historical period is 1981-2000 and the near future period is 2031-2050 (see **Figure 1.6**).

1.3.1.3. Fire Weather Index (FWI)

The FWI system provides numerical non-dimensional ratings of relative fire potential for a generalized fuel type (mature pine stands) based solely on weather observations. FWI is part of the Canadian Forest Fire Danger Rating System established in Canada since 1971 (van Wagner, 1987). Furthermore, since 2007, FWI has been adopted at the EU level and used in a harmonized way throughout Europe by the European Forest Fire Information System (EFFIS) of the Copernicus Emergency Management Service (since 2015). The index was calculated for the fire season (defined from May to October) for all models, scenarios and periods.



HUMIDITY	INDEX-DISCOMFORT LEVEL
<29°C	comfortable
30-34°C	some discomfort
35-39°C	discomfort; avoid intense exertion
40-45°C	great discomfort; avoid exertion
46-53°C	significant danger; avoid any activity
>54°C	imminent danger; heart stroke.

Figure 1.6. Number of days per year with Humidex > 35 °C (Euro-CORDEX).
Source: SOCLIMPACT project deliverable D4.3. Atlases of newly developed indexes and indicator.

For the Azores islands, under the scenario (B1), the class of hazard changes from low to high in the normalized FWI (nFWI), but the actual FWI remains low. It is important to note that when using normalized data, in order to compare different time periods and scenarios, only the lowest and the highest grid point values are considered. Additionally, FWI results include temperature, precipitation, relative humidity and wind. It is not only a matter of temperature (which is in fact higher under A1B). This is, during the days with high temperatures and high relative humidity (as Azores are in the middle of the ocean), the index values are expected to decrease, which seems to be the scenario A1B (see **Figure 1.7**).

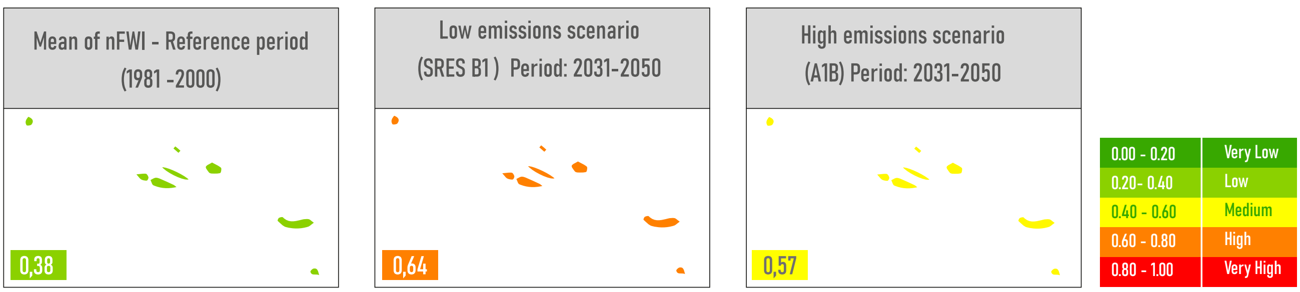


Figure 1.7. Fire Weather Index (ESCENA) with the color associated to the class of hazard.
Source: SOCLIMPACT Deliverable Report D4.4c Report on potential fire behaviour and exposure.

1.3.2. Aquaculture

The predicted impacts of climate change on the oceans and seas of the planet are expected to have direct consequences on marine based aquaculture systems. The basic effects are the following (Soto and Brugere, 2008):

- Changes in biophysical characteristics of coastal areas.
- Increased invasions from alien species.
- Increased spread of diseases.
- Changes in the physiology of the cultivated species by changing temperature, salinity, oxygen availability and other important physical water parameters.
- Changes in the differences between sea and air temperature, which will alter the seasonality, frequency and severity of storms, cyclones and other extreme events, affect the stability of the coastal resources and potentially increase the damages in infrastructure.
- Sea level rise, acidification, changes in precipitation and other effects will also add to the changes in coastal ecosystems and environment, thus affecting production and infrastructure (=investments).

1.3.2.1. Annual Mean Significant Wave Height (AMSH)

Annual Mean Significant Wave Height was selected as a relevant average indicator. For the Atlantic as a whole, no major changes in wave height mean values are observed in the model results, but there is a northward shift of the zonal belt where the meridional gradient of the field is strongest. Concerning the Azores, the AMSH could be decreased under RCP8.5 (far future) (see **Figure 1.8**).

1.3.2.2. Extreme Wave Return Time

Return times for a threshold of 7 m significant wave height (hs) were computed. This threshold for the significant height was identified by stakeholders as the critical limit for severe damages to assets at sea, for both the near (2046-2065) and the far (2080-2100) time horizons. Return times can be related to the payback times of investments and help assess potential economic losses and economic sustainability. The hazard for the Azores remains virtually unchanged (see **Figure 1.9**).

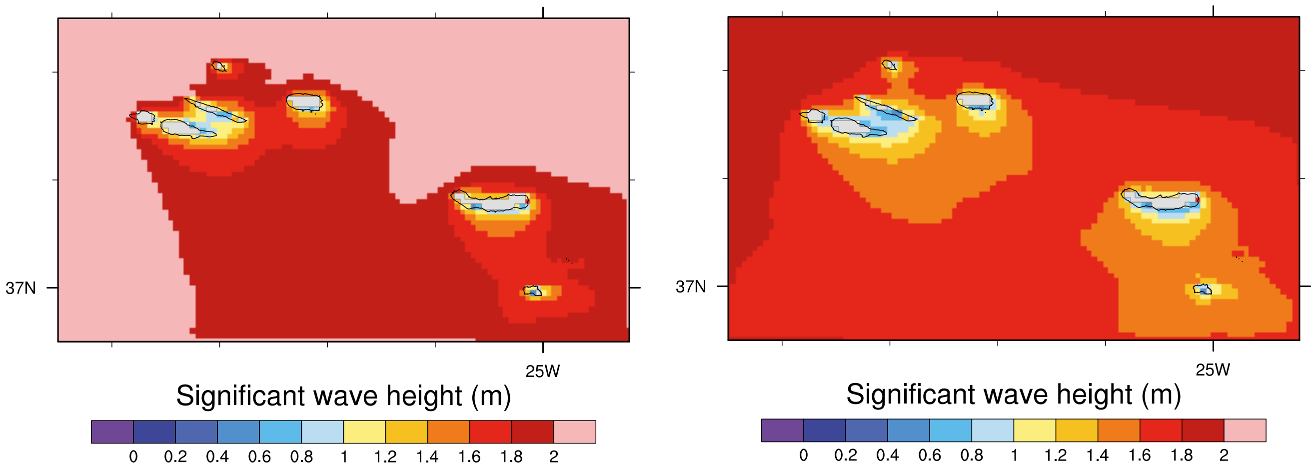


Figure 1.8. Annual Mean Significant Wave Height for present conditions (left) and projections under scenario RCP8.5 for far future (2081-2100).
Source: SOCLIMPACT Project deliverable D4.3. Atlases of newly developed hazard indexes and indicators.

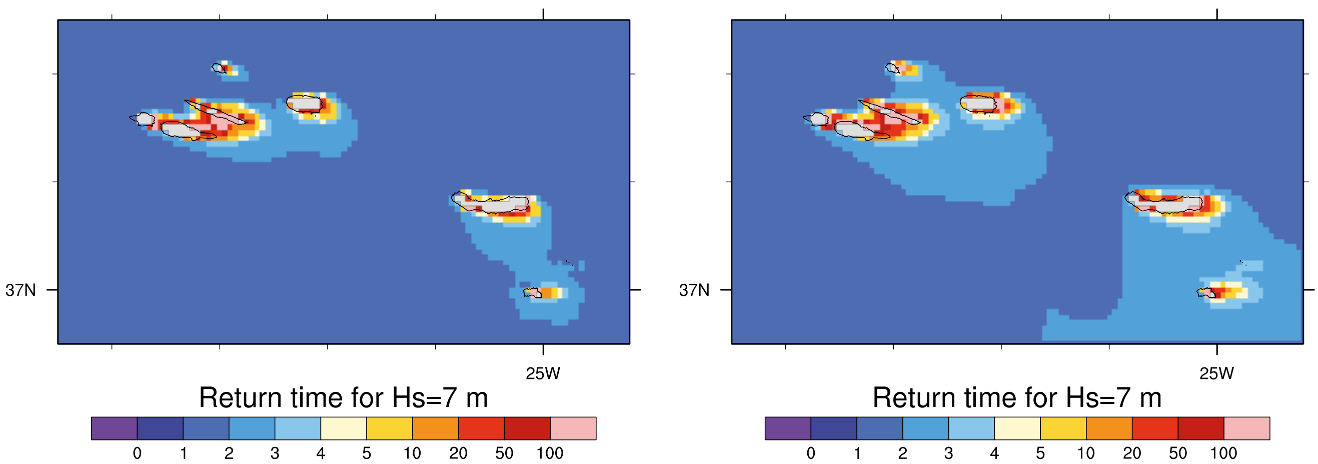


Figure 1.9. Extreme wave return under present climate and under RCP8.5 (far future).
Source: SOCLIMPACT Project deliverable D4.3. Atlases of newly developed hazard indexes and indicators.

1.3.3. Energy

1.3.3.1. Cooling Degree Days (CDD)

Climate change may impose welfare reductions to the European islands' societies by affecting thermal comfort. Cooling Degree Days (CDD) are a measure of how much (in degrees), and for how long (in days), outdoor air temperature is higher than 21 °C. It is found that the CDD values triple according to the A1B scenario, while they are more than double for the B1 (see **Figure 1.10**).

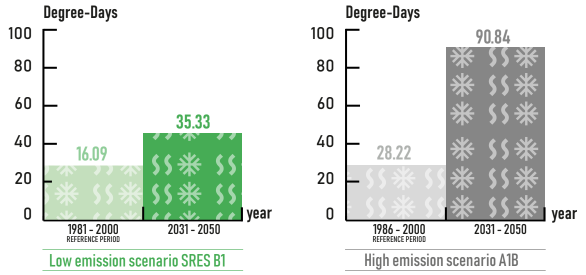


Figure 1.10. Cooling Degree Days.

Source: SOCLIMPACT Project deliverable D4.3. Atlases of newly developed hazard indexes and indicators.

1.3.4. Maritime Transport

1.3.4.1. Sea Level Rise (SLR)

Sea Level Rise (SLR) is one of the major threats linked to climate change. It would induce permanent flooding of coastal areas with a profound impact on society, economy and environment. Moreover, an increase in the mean sea level would result in a larger impact of coastal storms with the consequent increase of risk. The results are presented in terms of mean sea level rise. For the Azores Islands, the SLR ranges from 24 cm (RCP2.6) to 69 cm (RCP8.5) at the end of the century (see **Figure 1.11**).

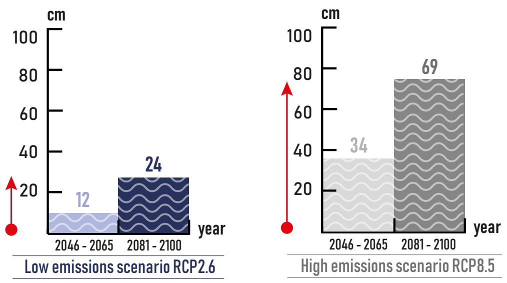


Figure 1.11. Mean sea level rise (in cm) with respect to the reference period (1986-2005). Own elaboration based on global and regional simulations.

Source: SOCLIMPACT Deliverable Report D4.4b Report on storm surge levels.

1.3.4.2. Wind extremes

The wind extremity index NWIX98 is defined as the number of days per year exceeding the 98th percentile of mean daily wind speed. This number decreases in the far future under RCP8.5 (- 24%). Like the NWIX98, the 98th percentile of daily wind speed itself, WIX98, decreases under RCP8.5 (see **Figure 1.12**).

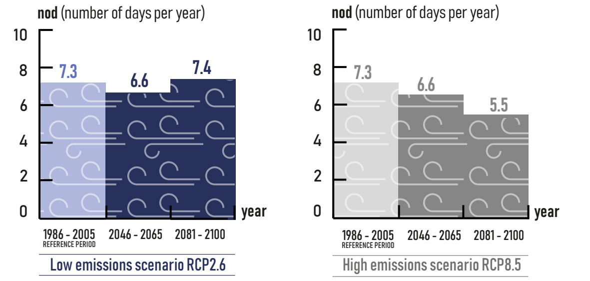


Figure 1.12. Wind Extremity Index (NWIX98). Ensemble mean of the MENA-CORDEX simulations.

Source: SOCLIMPACT Deliverable Report D4.3. Atlases of newly developed indexes and indicators.

1.3.4.3. Wave extremes (99th percentile of significant wave height averaged)

Marine storms can have a negative impact on maritime transport, coastal-based tourism and aquaculture, among other activities. To illustrate this impact, the 99th percentile of significant wave height averaged has been chosen. A decrease in the extreme wave height is found being larger under scenario RCP8.5. In relative terms, the averaged changes are lower than 10% even under the RCP8.5 (see **Figure 1.13**).

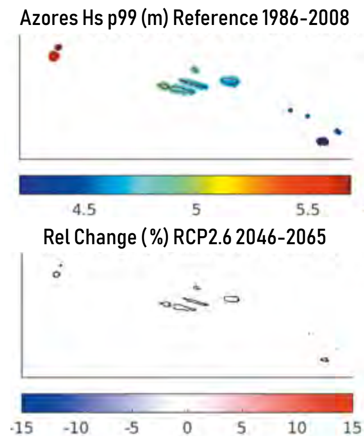


Figure 1.13. The 99th percentile of significant wave height averaged for the reference period and the relative change for the RCP8.5. Global simulations produced by Hemer *et al.* (2013).

Source: SOCLIMPACT Deliverable Report D4.4b Report on storm surge levels.

1.4. Risk Assessment

1.4.1. Tourism

1.4.1.1. Risk of forest fires and loss of attractiveness

Forest fires are considered an important parameter for the attractiveness of tourist destinations. Severe episodes were met in Algarve (Portugal) and Greece (Athens area) in the recent period, threatening the tourist seas. For the Azores islands, which are not included or are included marginally in the EURO and MENA-CORDEX domains, the ESCENA Project model results (Jiménez-Guerrero *et al.*, 2013) were employed. They have been produced under the AR4 IPCC scenarios with 25 km spatial resolution. Here, SRES B1 and A1B scenarios were selected, considered to be closer to RCP2.6 and RCP8.5, respectively. The historical period (reference) is 1981-2000 and the near future period is 2031-2050. The score of risk is low for the Azores during the current period and for the near future. Under the scenario B1, the risk will be medium (see **Figure 1.14** and **Figure 1.15**). However, it should be taken into account that the normalization of results made for the FWI (nFWI) contributes to increase this score.

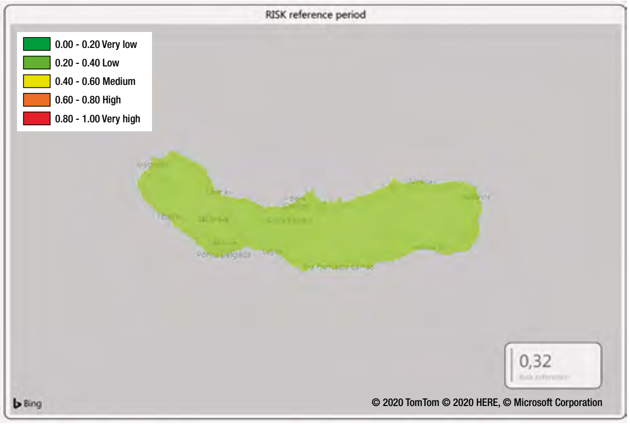


Figure 1.14. Risk score for the reference period.

Source: SOCLIMPACT Deliverable Report – D4.5. Comprehensive approach for policy makers.

1.4.2. Aquaculture

1.4.2.1. Risk of increased fragility of aquaculture activity due to extreme weather events

The objective of the risk assessment is to obtain final risk scores according to a gradient (very low to high) and to be able to compare the European islands with each other. For the Atlantic islands, two models are available (Hadley Centre and ACCESS) for data on return time. As can be seen in the **Table 1.4,** the results of these models are highly variable.

For the Azores even the change of the risk is different, where the Hadley model shows a decrease in risk while ACCESS

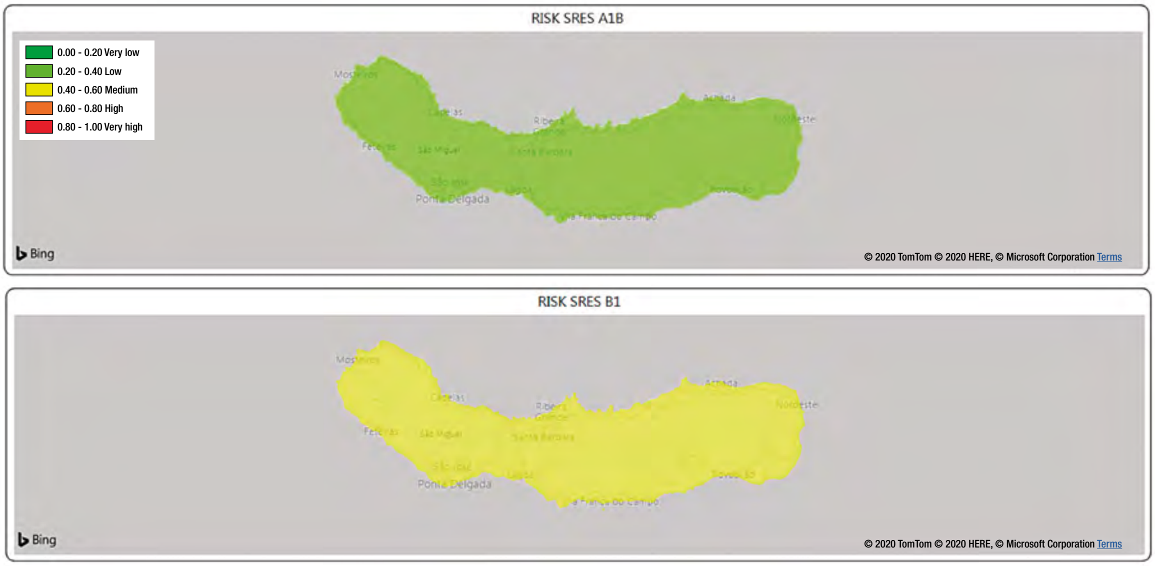


Figure 1.15. Risk score for scenarios for SRES B1 and A1B (near future).

Source: SOCLIMPACT Deliverable Report – D4.5. Comprehensive approach for policy makers.

shows a significant increase in risk. Therefore, no conclusion can be made. For Madeira, the risk in the future will be non-existent. Not considering probability, it could be concluded that climate change has a positive or no effect on the occurrence on extreme events in Madeira. However, since this data is not accurate, more work needs to be done (see **Table 1.4**).

Table 1.4. Risk results for the Atlantic Islands.

	Hadley centre			ACCESS		
Risk	Historic	RCP 8.5 Mid century	RCP 8.5 End-century	Historic	RCP 8.5 Mid century	RCP 8.5 End-century
Azores	0.83	0.76	0.79	0.15	0.41	0.67
Madeira	0.20	0	0.01	0	0	0

Source: SOCLIMPACT Deliverable Report - D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

1.5. Impacts on the Blue Economy Sectors

1.5.1. Tourism (Non-Market Analysis)

In order to analyse the reactions of tourists to the impacts of climate change and the preferences for adaptation policies, several hypothetical situations were posed to 300 tourists visiting Azores, whereby possible climate change impacts were outlined for the island (i.e., beach erosion, infectious diseases, forest fires, marine biodiversity loss, heat waves, etc.).

Firstly, tourists had to indicate whether they would keep their plans to stay on the island or find an alternate destination if the impact had occurred, which allows predictions of the effects on tourism arrivals to be made for each island. Secondly, tourists were asked to choose between various policy measures funded through an additional payment per day of stay. The tourists' choices being an expression of their preferences for attributes/policies. To estimate the results, the conditional logit model was run by using the Stata software (see **Figure 1.16**).

In general, data confirms that tourists are highly averse to marine wildlife disappearing to a large extent (75.30 % of tourists would change destination). Moreover, they are not willing to visit the islands when there is risk of infectious diseases becoming more widespread (72.70 %) or when water is scarce for leisure activities (57.70 %). In addition, policies related to marine habitats restoration (10 €/day), water supply reinforcement (8.4 €/day) and cultural heritage protec-

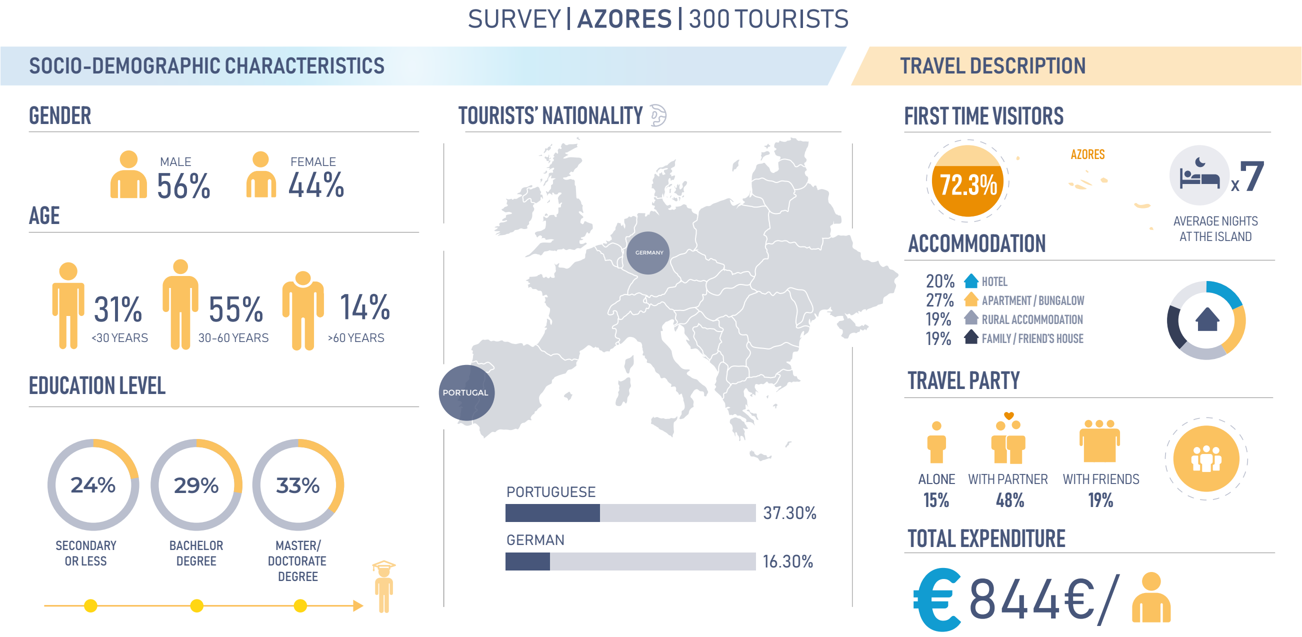


Figure 1.16. Socio-economic characteristics and travel description: tourists visiting Azores.

Source: SOCLIMPACT Deliverable Report - D5.5. Report on market and non-market costs of Climate Change and benefits of climate actions for Europe.

tion (6.3€/day) are the most valued, on average, by tourists visiting these islands.

Although climate change impacts are outside the control of tourism practitioners and policy-makers, they can nevertheless utilise this knowledge to improve the predictable effect of certain adaptation policies and risk management strategies, and develop their plans accordingly (see **Figure 1.17**).

The impact of increased temperatures and heat waves on hotels' prices and revenues

In order to assess how the variation in temperature has an impact on the tourism sector through changes in tourism demand, our research question was: "How do increasing temperatures (and heat waves) impact prices and, more in general, expenditure of tourists?" Arguably, when temperatures grow, tourists adjust their behaviour: they might switch destination, or they might stay longer or shorter depending on their attitudes and preferences. In turn, all these changes modify the market equilibrium, pushing tourism companies to adjust their prices to re-establish the equilibrium between demand and supply. The change in demand and the change in price determine the change in tourism expenditure which is, from the destination's perspective, tourism revenue.

We monitored current weather conditions posted on several weather forecast providers and daily prices posted on Booking.com by hotels. We then estimated the link between daily temperature and daily price, controlling for all the other factors affecting prices. We finally applied these estimates to the increase in the number of days with excessive temperature projected for the future in two scenarios (RCP2.6 and RCP8.5) and in two time horizons (near future, about 2050, and distant future, about 2100).

Among the different indicators linked to thermal stress, we focus on two: the number of days in which the temperature is above the 98th percentile and the number of days in which the perceived temperature is above 35 °C. Although the impact for both indices were computed, in this document we only report the second one (named Humidex) because it is the most intuitive and because human thermal stress is more related to the absolute value of the temperature than its deviation from some pre-determined distribution. We assumed that thermal stress appears when the perceived temperature grows above 35 °C.

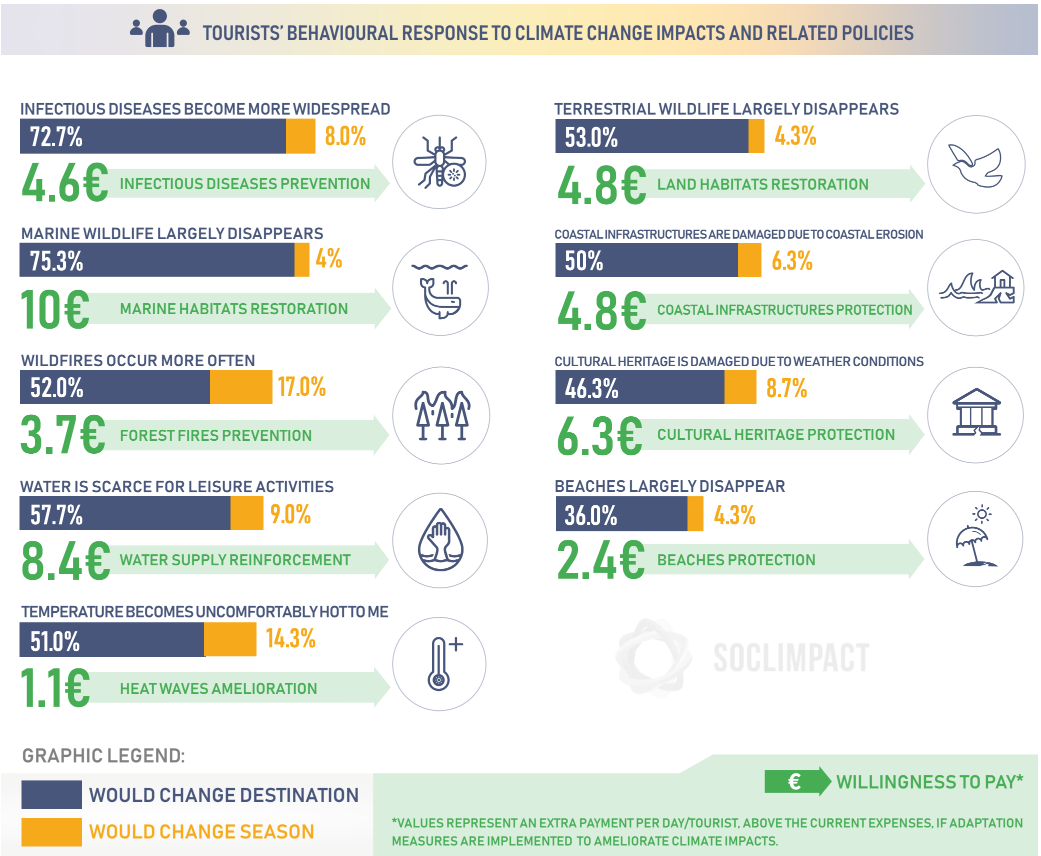


Figure 1.17. Tourists' response to climate change impacts and related policies: tourists visiting Azores.

Source: SOCLIMPACT Deliverable Report - D5.5. Report on market and non-market costs of Climate Change and benefits of climate actions for Europe.

As thermal stress is delimited in the summer months, and this is when the great majority of tourists arrive in these islands, the whole analysis has been carried out in six months only: from May to October included. In other words, we assume that there is no thermal stress (and hence no impact on tourism) in the rest of the year.

Initially, three islands were investigated: Corsica, Sardinia, and Sicily, given the massive amount of potential data. Other estimations were provided for the Azores using the Index of Distance in Destination Image to position each island in a range that goes from Sardinia / Corsica on one side and Sicily on the other side. Without entering the details of the extrapolation method a summary of results is reported here (see **Table 1.5**).

According to these findings, the average increase in temperature, which is correlated to a growing thermal stress for tourists, brings an economic advantage to tourism destinations. This is only an apparent contradiction with previous findings. This study does not neglect the fact that if islands are too hot, tourists will choose to move to other (cooler) destinations, that in principle exist. Then, the increase in tourism (and tourism revenues) stems from the fact that, when the temperature is too hot, people would prefer to move to coastal areas (where the climatic conditions are more bearable) than staying inland or in cities. Future trends will also facilitate this pressure of tourism demand (think about the spreading of smart working activities where, in principle, the worker can relocate wherever he/she wants).

Table 1.5. Estimation of increase in average price and revenues for Azores.

Actual share of days in which Humidex > 35 degrees	Future scenario considered	Days in the corresponding scenario in which Humidex > 35 degrees	Increase in the average price	Increase in the tourism overnight stays	Increase in tourism revenues
8.93%	RCP 2.6 near	14.88%	2.4%	0.5%	2.9%
	RCP 8.5 near	18.38%	3.8%	0.8%	4.5%

Source: SOCLIMPACT Deliverable Report-D5.3. Data Mining from Big Data Analysis.

1.5.2. Energy

Climate change may impose welfare reductions to the European islands' societies by affecting thermal comfort. Cooling Degree Days (CDD) are a measure of how much (in degrees), and for how long (in days), outdoor air temperature is higher than 21 °C. The CDD is used as a measure of the energy needed to cool buildings. The increase in CDD and the energy demand (GWh/year) for cooling were estimated for the islands, under different scenarios of global climate change.

Under the high emissions scenario, it is expected that the CDD increases to 91 CDD approximately. Under this situation, the increase in cooling energy demand is expected to be 936% (see **Figure 1.18**).

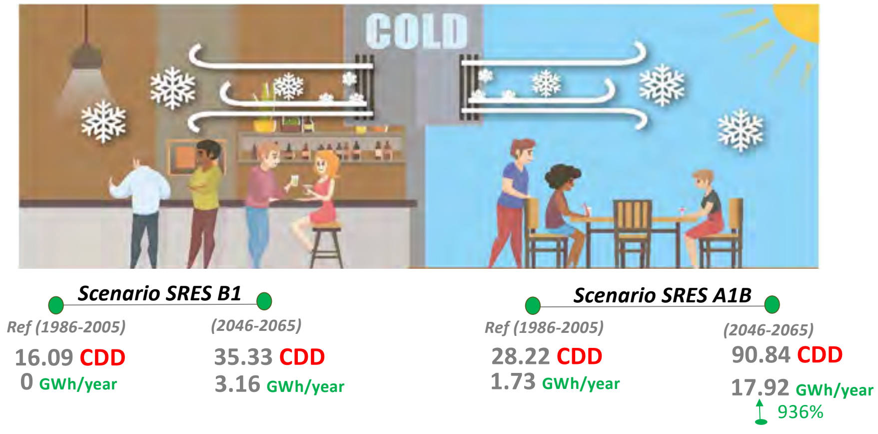


Figure 1.18. Estimations of increased energy demand for cooling in Azores under different scenarios of climate change until 2100.

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from Climate Change impacts to GEM-E3-ISL and GINFORS models.

1.5.3. Maritime Transport

For maritime transport, an estimation has been made on the impact of Sea Level Rise on the ports' economy of the island. The costs have been calculated with reference to 1 meter; this is, the investment needed to increase the infrastructures' height by 1 meter. There is not necessarily a strict correspondence between the SLR and the required elevation of port infrastructures, which also depends on the coastal hydrodynamic and the shape of dikes of each port. By experts' recommendation, we have assumed that 1 meter increase in port height is required to cope with the SLR under RCP8.5 scenario of emissions. A linear extrapolation was used to estimate this height for other RCP scenarios.

The starting point was the identification of the principal ports in each island (economic relevance). Second, the analysis of the different port areas (exterior, ramps, oil, etc.), and their uses. Third, the elevation costs were estimated per each area and port separately (considering 1 meter elevation). Thus, the costs of 1 meter elevation presented are the sum of all areas and ports analysed, and including the rest of the ports of the island (if applicable) based on proportionality. Estimations consider that all ports of the entire area should be elevated at the same time. In other words, the economic values can be interpreted as the depreciation (amortization) costs of the investment needed to increase all ports' infrastructures in the island for 125 years time horizon. No discount rate has been applied.

As expected, the rising of sea levels will affect the sector, as new investments will be needed to keep ports' operability. Under the high emissions scenario, it is expected that these costs could increase 357,000.00 euros per year until the end of the century (see **Figure 1.19**).

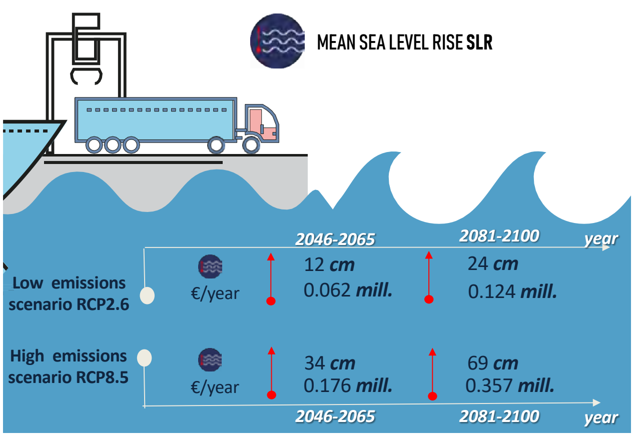


Figure 1.19. Increased costs for maintaining ports' operability in Azores under different scenarios of SLR caused by climate change until 2100.

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

1.6. Impacts on the Island's Socio-Economic System

The aim of our study is to assess the socio-economic impacts of biophysical changes in the Azores. For this purpose, we have used the GEM-E3-ISL model, a single-region, multi-sectoral general equilibrium model based on the principles of neo-classical theory, and GINFORS, a macro-econometric model based on the principles of post-Keynesian theory.

Both models include 14 sectors of economic activity, with an emphasis on services and specifically on those composing the tourism industry. The GEM-E3-ISL model also includes endogenous representation of labor and capital markets as well as bilateral trade flows by sector.

Changes in the mean temperature, sea level and precipitation rates are expected to affect energy consumption, tourism flows and infraestructure. These impact-chains have been examined and quantified under two emission pathways: RCP2.6, which is unlikely to exceed 2°C of global surface temperature increase by the end of the century considering Preindustrial (1850-1900) reference period, and RCP8.5, which is a high-emission scenario. The impact on these three factors was used as input in the economic models, which then assess the effects on GDP, consumption, investments, employment, etc.

In total, 14 scenarios have been quantified for Azores. The scenarios can be classified in the following categories:

1. Tourism scenarios: these scenarios examine the reduction in tourism revenues due to changes in human comfort as captured by the hum-index, the degradation of marine environment, the increased risk of forest fires and beach reduction. The aggregate tourism scenario (TOUR-SC6) assesses the economic impacts of a simultaneous change of all (the above-mentioned) factors.
2. Energy scenarios: the aggregate energy scenario (ENER-SC3) assessed the impacts on regional economic performance of increased total electricity demand driven by cooling and water desalination demand.
3. Infrastructure scenario: this scenario assesses the impact of port infrastructure damages (INFRA-MAR).
4. Aggregate scenarios: these scenarios examine the total impact of the previous-described changes in the economy.

In the aggregate scenario, we examine the impacts of a simultaneous change in electricity consumption, tourism revenues and infrastructure damages. The scenario specifications for the two climatic variants are presented below (see **Table 1.6**).

The theoretical and structural differences of the two models mean that this study produces a reasonable range of impacts, given the uncertainty embodied in economic analysis and especially in the long-term.

Table 1.6. Aggregate scenario –inputs.

	Tourism revenues (% change from reference levels)	Electricity consumption (% change from reference levels)	Infrastructure damages (% of GDP)
RCP2.6 (2045-2060)	-20.62	0	-0.04
RCP2.6 (2080-2100)	-25.40	18.24	-0.04
RCP8.5 (2045-2060)	-33.03	0	-0.10
RCP8.5 (2080-2100)	-40.56	33.10	-0.12

Source: SOCLIMPACT Deliverable [Report - D5.6](). Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

In GEM-E3-ISL, the economy is in equilibrium at each point in time. Prices adjust to ensure that supply equals demand (market clearing), capital is fully used; however, the model allows for equilibrium unemployment as it takes into account labor market rigidities. The impacts are driven mainly by the supply side through changes in production costs which influence relative prices; hence, competitiveness and trigger substitution effects. The GEM-E3-ISL model assesses the impacts on the economy up to 2100.

The macro-econometric type of models, such as GINFORS, do not require that all markets are in equilibrium; idle capital and involuntary unemployment are some other features of this type of models where the results are driven mainly by adjustments in the demand side of the economy. The GINFORS assesses the impacts on the economy up to 2050.

With respect to GDP, the estimated change compared to the reference case is between -0.3% and -3.1% in the RCP2.6 in 2050 and between -0.8% and -4% in the RCP8.5. The cumulative change over the period 2040-2100 is estimated (by GEM-E3-ISL) to be equal to -2.8% in the RCP2.6 and -6.5% in the RCP8.5. The disaggregation of total impacts implies that higher electricity consumption for cooling and desalination purposes exerts higher pressure on the economy compared to the other two components examined (i.e., tourism and infrastructure).

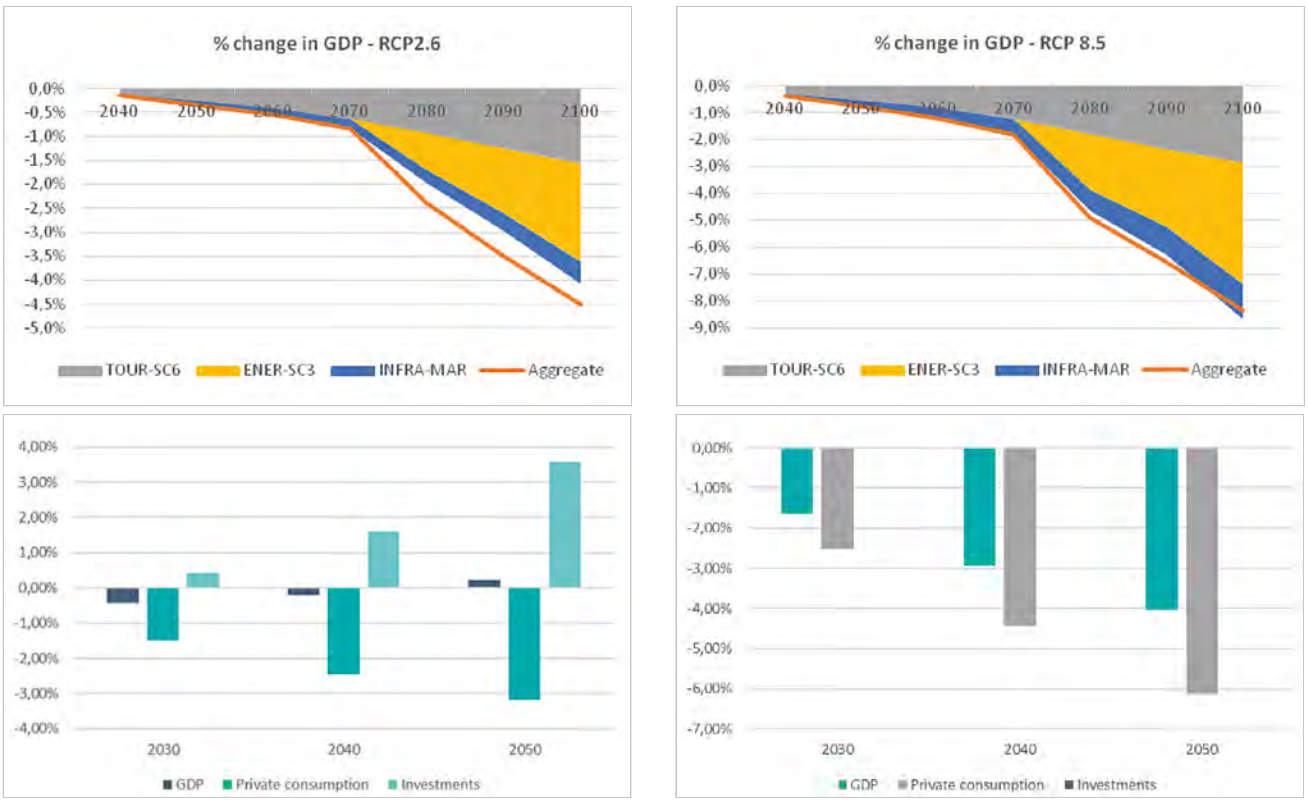


Figure 1.20. Percentage change in GDP. GEM-E3-ISL results (above), GINFORS (below).

Source: own calculation.

With respect to sectoral impacts, both models show a significant decrease in the activity of tourism related sectors and an increase in the activity of the primary and secondary sectors (see **Figure 1.21**).

Overall employment falls, and especially in tourism related sectors, following the slowdown in domestic activity. In GEM-E3-ISL, employment increases in non-tourism related activities due to labor costs reductions (as regional wages fall, and their competitiveness increases) which leads to a substitution of capital with labor in other sectors of the economy. Employment falls on average by 0.2% in the RCP2.6 and by 0.3% in the RCP8.5 (see **Figure 1.22**).

Figure 1.21. Production percentage change from reference: GEM-E3-ISL results (above), GINFORS (below).

Source: own calculation.

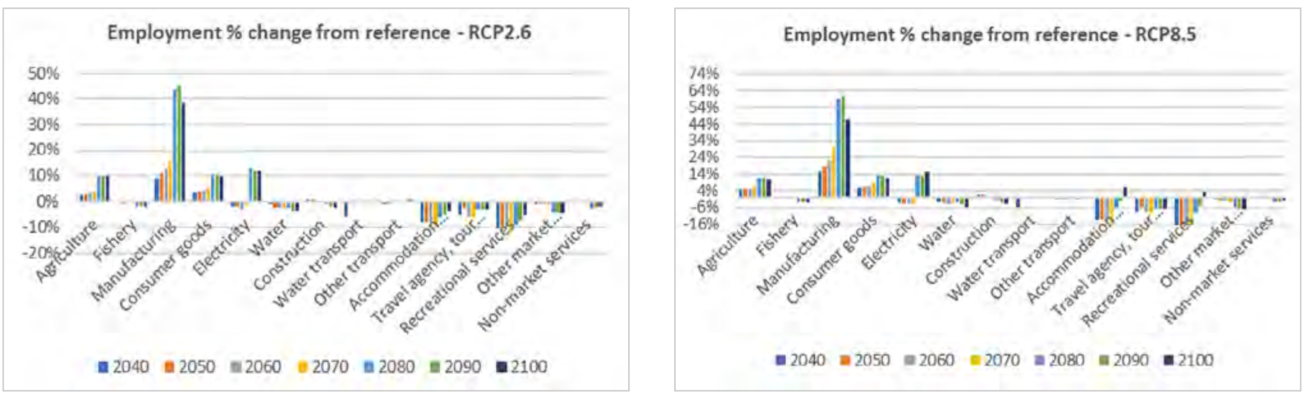


Figure 1.22. Employment percentage change from reference, GEM-E3-ISL results.

Source: own calculation. ***(Continued on the next page)***

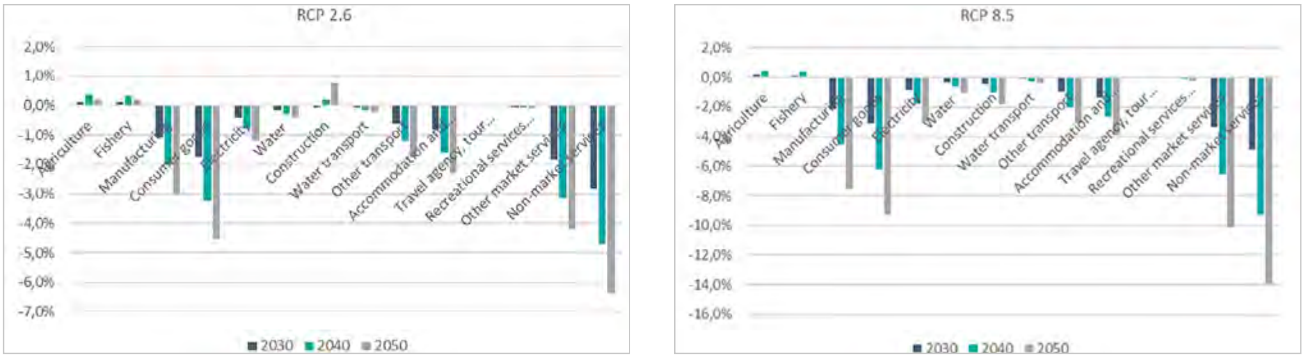


Figure 1.22 (Cont.). Employment percentage change from reference: GWS results.

Source: own calculation.

1.7. Towards Climate Resiliency

The Azores approved its Regional Strategy on Climate Change (ERAC) in 2011 (Resolution 123/2011). The ERAC is to be put into action through the Regional Program for Climate Change (PRAC) approved by the Resolution of the Council of the Government 93/2014. The PRAC is focused in mitigation and adaptation to climate change of major economic sectors and natural assets, and their interaction with the climate.

Since its conclusion and public presentation in November 2017, PRAC was approved in 2019 by the regional autonomous government. The SRIERPA (Sistema Regional de Inventário de Emissões por Fontes de Remoção por Sumidouros de Poluentes Atmosféricos), a regional system of inventory and monitoring of carbon sinks and emissions, that feeds the IRERPA (Inventário de Emissões por Fontes de Remoção por Sumidouros de Poluentes Atmosféricos), was created within the scope of PRAC (Despacho n.° 84/2018). This inventory produces results that comply with IPCC methods and that can be fully integrated with the national inventory system INERPA (Inventário Nacional de Emissões Atmosféricas), using the CRF (Common Reporting Format) and producing the NIR (National Inventory Report).

The context for decarbonization in islands has challenges (and opportunities) recognized by the European Clean energy for EU islands framework. Despite this context and the fact that the Azores are a European outermost region, the autonomous regional government has been successful in pushing forward the decarbonization process in the last decades. The region still continues to announce its commitment to renewable energy and future investments. However, a dependency on fossil fuels still remains, as the energy power generation is still 60% fossil fuel based in the hole region (EDA, 2020). One of the reasons of this dependency is isolation and the fact that economies of scale are more challenging in this context. Furthermore, the region still needs to subsidize fossil fuels for the energy and the transport sector. Putting an end to these subsidies can help to continue to push forward the decarbonization process, but stable and accessible alternatives must be made available to the region. The economy and islanders need this solid support as to ensure that "no person and no place are left behind" (European Green Deal, 2021).

The expansion of renewable energy sources in the electric sector continued, for instance in 2017, the geothermal electricity plant started operating with 4 MW of stable production. The project started in the year 2000, first drills where made in 2007 and in 2015 the installation of a (predicted) 3.5 MW went underway. This facility will provide 10% of the electricity, and intentions exist to increase the available power. There has been also the announcement of an energy plan with the 2030 horizon (Estratégia Açoriana para a Energia 2030) and a plan for the electrification of mobility (Estratégia para a Implementação da Mobilidade Elétrica nos Açores) which aims to have 2000 electric vehicles in the islands by 2030 as well. Both for the adaptation and mitigation part, the PRAC contains recommendations regarding electric mobility that may shape its' future course.

To sum-up, the region's commitment to fight climate change and deal with its risks, let us consider:

Risk:

Improve the research capacity:

- Climate;
- Monitorization;
- Vulnerability assessment.

Mitigation:

- Promote low carbon economy;
- GEE emission sustainable reduction;
- Integrate the mitigation objectives in the sectors.

Adaptation:

- Build resilience for the territory;
- Promote adaptative capacity on key sectors;
- Integrate the mitigation objectives in the sectors.

Specific limits and obstacles

The major constrain in this territory is the fact that this is an outermost region, some 1600 kms away from mainland Portugal (locally referred to as the continent). The dimension of some islands leads to a lack of critical mass to achieve economies of scale, making the Azores autonomous region economically dependent on the outside. This reality is aggravated by the fact that this archipelago is very spread out, stretching 600 kms from its further corners and very much dependent on air and sea transport. The sea ports and airports tend to be oversized to ensure (whenever possible) regular direct connections to the mainland (where feasible), even in rough conditions, as those found in north Atlantic (frequent) storms.

Each island has an isolated electrical grid as the connection between different islands has not been possible to attain. A connection between Faial and Pico islands had been tried but failed due to technical difficulties. The advent of a sustainable energy grid linking some of the five islands of the central group could reshape their energy system, reducing context costs, increasing quality, reliability of service and ensuring the feasibility of further development of renewable energy.

The problem of an evident lack of high-resolution wave simulations comprising this Atlantic island is a limiting factor for the analysis of climate change impacts. While the Mediterranean region is sufficiently covered by already available wave and surge data, available wave climatology over the Atlantic Ocean has an overly low resolution. As a result, there is no good source of regional climate model data for the Azores, which are not included in the MENA-CORDEX ensemble. Stakeholders should be made aware that uncertainty is an inherent characteristic of climate data, and that any future planning must cope with it.

There is also a lack of reliable statistics and information related to exposure and vulnerability of the island to climate change. These are important components that worsen climate risks and respond to human interventions (more pressure). The island's adaptation focus should be, first, the development of reliable information systems for the periodic monitoring of these components.

1.7.1. Policy recommendations

A stakeholders consultation process was carried out in the island, aiming to propose, analyse and rank alternative adaptation measures for the island. The profile of the individuals participating in these focal groups involved policy and decision-makers, practitioners, non-governmental and civil society organisations, science experts, private sector, business operators and sector regulators at island level.

The main aim of these meetings was:

1. Identify and present the characterized packages of adaptation and risk management options for the island.
2. Develop detailed integrated adaptation pathways in three timeframes: Short term (up to 2030), Mid-century (up to 2050) and End-of-century (up to 2100).
3. Evaluate and rank adaptation options for 3 blue economy sectors in the island (energy, maritime transport and tourism).

To this aim, stakeholders utilized five evaluation criteria to rank the proposed measures:

- Cost efficiency: Ability to efficiently address current or future climate hazards/risks in the most economical way.
- Environmental protection: Ability to protect the environment, now and in the future.
- Mitigation win-wins and trade-offs: Current ability to meet (win-win) or not (trade-off) the island / archipelago's mitigation objectives.
- Technical applicability: Current ability to technically implement the measure in the island.
- Social acceptability: Current social acceptability of the measure in the island.

Four scenarios of intervention were analysed, called Adaptation Policy Trajectories which are different visions of future policy adaptation choices:

- APT A Minimum Intervention - Low investment, low commitment to policy change.
- APT B Economic Capacity Expansion - High investment, low commitment to policy change.
- APT C Efficiency Enhancement - Medium investment, medium commitment to policy change.
- APT D System Restructuring - High investment, high commitment to policy change.

It was assumed that adapting to climate change may range from minimal to high cost, and from requiring a small or incremental change to a significant transformation from the *status quo.* However, not all APT scenarios were considered in all islands, when they had a clear vision on the types of measures with greatest viability. Therefore, the final set of proposed adaptation measures are framed in the islands' socio-economic and political context, have a sectoral perspective, and respond to the islands' future scenarios of climate change. At the same time, the involvement of regional stakeholders in policy design allows them to engage in the effective implementation of climate actions on their island.

In appendices from K to N, a brief explanation of each adaptation option can be found, classified by type or class: Vulnerability Reduction, Disaster Risk Reduction, Social-Ecological Resilience, and Local Knowledge. The latest group refers to very specific measures proposed by stakeholders in each island to ratify their needs. Stakeholders were asked to make a choice between two Adaptation Options available per class of adaptation, under each ATP context.

1.7.1.1. Tourism

Overall, the adaptation pathways for the tourism sector in Azores are characterized by a significant heterogeneity across adaptation objectives. The diversification of the activities and products are preferred options in the longer term than other measures such as awareness campaigns. Beach nourishment (or replenishment) was valued in the beginning of the century while towards the end of the century, the regional preference goes to desalination.

Under APT B and D scenarios, the financial capital measures that were selected to address Vulnerability Reduction indicate that the region is initially centred on the development of economic policy Instruments and later on financial incentives to retreat from high-risk areas (medium to long term). The selection of the financial incentives to retreat in the end of the century can be related with the perception that the risks will increase over time.

To adapt via human capital, the diversification of the activities and products in opposition to awareness campaigns should be implemented. However, in Minimum Intervention scenario (APT A), investment in public awareness can be appropriate for short and mid-terms. At the same time, within a System Restructuring scenario (APT D), in all time periods, the diversification of the activities and products gain importance. The same pattern occurs for social capital, where awareness campaigns were selected for the short-term in opposition to local circular economy which gain relevance in the middle and long-term.

The option related with water restrictions and cuts (natural capital) was excluded from all periods when a System Restructuring scenario (ATP D) is used as a context, but was selected in an Efficiency Enhancement scenario (APT C) in middle and long term. The pathways developed seem to consider the growing evolution of the climate change risks and the urgency to respond to them.

This rationale is coherent with the physical capital options taken in APT B. Beach nourishment (or replenishment) was valued in the beginning of the century while towards the end of the century, the region shifted its preference to desalinization.

For Disaster Risk Reduction (DRR), and to manage long term risk, the decisions need to be sensible to the level of investment and reflect the climate change risk identified for the region. Coastal protection is a priority for the region throughout the scenarios where the level of investment and commitment are median to high - APTs B, C and D. In opposition, for APT A, drought and water conservation plans are a priority in the short and middle term. In Azores, adequate improvement of water harvesting from waterlines is possible in a scenario of low investment.

The Efficiency Enhancement scenario (ATP C) is the only scenario which considers the preparedness class. In the short and mid-term, mainstreaming Disaster Risk Management (DRM) was selected in detriment of using water to cope with heat waves. This result follows the risk response rationale, addressing disasters management in a first stage and heat waves when the risks related with temperature became higher towards the end of the century.

The risks related with fire were considered low in all time periods in Azores. The pathway clearly reflects the climate-risk context of the region which is considered to be low.

Generically, to address DRR in the tourism sector, it is necessary to continue to promote planning and allocate funds to develop climate change resilience in the region.

In Social-Ecological Resilience, groundwater management is not urgent for the sector in the short term. The region prefers, in the next decades (until 2050), to invest efforts in information systems to improve climate information reliability. In the end of the century, with a higher drought risk, the adaptation focus should be in groundwater management. This measure was selected in the scenarios where the commitment to policy is low (Minimum Intervention – ATP A and Economic Capacity Expansion – ATP B). For the scenarios with medium and high investment and commitment (ATP C and D), the policy options were selected in short to medium timeframes.

Options for regulation of natural services in the tourism sector will benefit from the maintenance of the rivers/valleys functions, creating recreational areas with a positive impact on tourism attractiveness. Regulating and maintenance services are only defined within medium and low commitment to policy change. In this context, coastal restoration is preferred only when the coastal risks are likely to increase,at the end of the century.

Since 2008, some islands have been under relevant meteorological droughts. For example, two years ago (2018) Azores faced a drought which originated indirect costs for the sector. During this period, it was necessary to implement measures such as water drilling or additional water treatment. Additionally, it was identified that some of the periods of drought have relevant implications in the crop yields and hence impact on the milk sector. However, droughts have been worsened by the agricultural activity specially because of animal husbandry (mainly by free grazing livestock that have a relevant freshwater input). There are specific areas in each island where the problem is worse, namely where soils are poorer and in low laying areas.

The potential impacts of a reduction in precipitation on the landscape and its indirect impact on tourism attractiveness were highlighted. Significant changes in landscape can be challenging for the tourism sector considering visitor's expectations and the promotion of the islands' natural resources. In this context, adapting tourism promotion was identified as a priority option.

In medium investment and medium commitment to policy change scenario (APT C - Efficiency Enhancement), cultural services are relevant. In this case, the region considered to dedicate efforts to preserve and minimize the impacts on biodiversity and ecosystems, while also preserving the attractiveness of the region.

Local Knowledge options were focused on the preservation and promotion of the natural attractiveness of the region and reflect the relevance of this issue for the Azorean tourism sector in the four pathways. All pathways reflect the need of conservation of the natural areas to continuously address multiple risks. This approach also aims to promote water resource availability without hard and irreversible infrastructures. The vector borne diseases were not considered urgent for this sector, as the agroforestry related otions do not have direct control over the health policy (see **Table 1.7**).

Table 1.7. Proposed adaptation options for tourism in Azores.

<table>
<tr><td rowspan="7">APT A – Pathway
—
Minimum Intervention
low investment, low commitment to policy change
—
This policy trajectory assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td colspan="2">Public awareness programmes</td><td>Activity and product diversification</td></tr>
<tr><td colspan="2">Drought and water conservation plans</td><td>Coastal protection structures</td></tr>
<tr><td colspan="3">Health care delivery systems</td></tr>
<tr><td colspan="2">Pre-disaster early recovery planning</td><td>Post-disaster recovery funds</td></tr>
<tr><td colspan="2">Monitoring, modelling and forecasting systems</td><td>Adaptation of groundwater management</td></tr>
<tr><td>Adapt tourism promotion to Climate Change risks</td><td>Define protection regime for “Maximum Infiltration Zones”</td><td>Improve Natura 2000 habitats – terrestrial, coastal and marine</td></tr>
<tr><td rowspan="9">APT B – Pathway
—
Economic Capacity Expansion
high investment, low commitment to policy change
—
This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td colspan="2">Economic Policy Instruments (EPIs)</td><td>Financial incentives to retreat from high-risk areas</td></tr>
<tr><td>Public awareness programmes</td><td colspan="2">Activity and product diversification</td></tr>
<tr><td colspan="2">Beach nourishment</td><td>Desalination</td></tr>
<tr><td colspan="2">Coastal protection structures</td><td>Drought and water conservation plans</td></tr>
<tr><td colspan="2">Monitoring, modelling and forecasting systems</td><td>Adaptation of groundwater management</td></tr>
<tr><td colspan="2">River rehabilitation and restoration</td><td>Dune restoration and rehabilitation</td></tr>
<tr><td>Define protection regime for “Maximum Infiltration Zones”</td><td>Adapt tourism promotion to Climate Change risks</td><td>Create water storage reservoirs to ensure water availability</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="11">APT C – Pathway
—
Efficiency Enhancement
medium investment, medium commitment to policy change
—
This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td>Activity and product diversification</td><td>Public awareness programmes</td><td>Activity and product diversification</td></tr>
<tr><td>Tourist awareness campaigns</td><td colspan="2">Local circular economy</td></tr>
<tr><td>Local sustainable fishing</td><td colspan="2">Water restrictions, consumption cuts and grey-water recycling</td></tr>
<tr><td colspan="2">Coastal protection structures</td><td>Drought and water conservation plans</td></tr>
<tr><td colspan="2">Mainstreaming Disaster Risk Management</td><td>Using water to cope with heat waves</td></tr>
<tr><td>Monitoring, modelling and forecasting systems</td><td>Adaptation of groundwater management</td><td>Monitoring, modelling and forecasting systems</td></tr>
<tr><td>River rehabilitation and restoration</td><td>Dune restoration and rehabilitation</td><td>River rehabilitation and restoration</td></tr>
<tr><td>Ocean pools</td><td colspan="2">Adaptive management of natural habitats</td></tr>
<tr><td>Improve Natura 2000 habitats – terrestrial, coastal and marine</td><td colspan="2">Adapt agroforestry systems to drought conditions</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="8">APT D – Pathway
—
System Restructuring
high investment, high commitment to policy change
—
This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td>Economic Policy Instruments (EPIs)</td><td colspan="2">Financial incentives to retreat from high-risk areas</td></tr>
<tr><td colspan="3">Activity and product diversification</td></tr>
<tr><td colspan="3">Local sustainable fishing</td></tr>
<tr><td colspan="3">Coastal protection structures</td></tr>
<tr><td colspan="2">Pre-disaster early recovery planning</td><td>Post-disaster recovery funds</td></tr>
<tr><td>Adaptation of groundwater management</td><td>Monitoring, modelling and forecasting systems</td><td>Adaptation of groundwater management</td></tr>
<tr><td>Improve Natura 2000 habitats – terrestrial, coastal and marine</td><td>Adapt agroforestry systems to drought conditions</td><td>Create water storage reservoirs to ensure water availability</td></tr>
</table>

Vulnerability Reduction | *Disaster Risk Reduction* | *Socio-Ecological Resilience* | *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

1.7.1.2. Maritime Transport

The Azorean maritime transport sector adaptation pathways are characterized by a significant heterogeneity across the four potential adaptation policy trajectories (APTs) upon which they are built.

In the Minimum Intervention (APT A) scenario which favours limited investment costs and the use of no-regret strategies, the Azorean maritime transportation sector follows a pathway of interventions that seek to sustain sector activities during and after the occurrence of extreme events. After that period, reinvestment in information and behavioural change will be necessary to respond to increasing climate related threats. Disaster Risk Reduction focuses on managing long term risks via climate proofing of infrastructure and activities while developing alternative routes during extremes events as a means of assuring Post-disaster recovery and rehabilitation of sector value chains. This strategy is complemented by disaster responses that include new procedures to handle service disturbances up to 2030 and the development of tailored automated Intelligent transport systems after that. Ecosystem resilience and provisioning services in this pathway take the form of tailored protection structures, first by using marine life friendly materials and, after 2030, by strengthening the nexus port protection-energy production.

The Capacity Expansion (APT B) and System Restructuring (APT D) scenarios offer a higher level of investment but diverge in the commitment to policy change, which is low on the first case and high on the later. In terms of human capital, differences across the two pathways developed in these scenarios are not significant. The only slight variation is an initial investment in behavioural change in APT B, that soon (after 2030) reverts to social dialogue, the preferred option in APT D throughout the century. The reason for such initial investment could be driven by a perceived small departure from the current *status quo* in a scenario where resources to invest are large, which in turn, translates in the need for additional education of the Archipelago's sector agents. In both pathways, financial capital is initially focused on incentives to retreat from higher-risk areas that are later followed by the deployment of risk-sharing mechanisms such as insurance. Natural capital options are only available in APT D (not in APT B), and in this scenario's pathway, after an initial focus on restricting the development in low-lying risk areas, there is a shift to the preservation of marketable natural resources via the investment in refrigeration and/or cooling systems. On the other hand, the APT B scenario includes the possibility to invest in physical capital. In this particular case, the Azorean maritime transport pathway clearly favours investments in the operability and flexibility of ports in detriment of vessels. In relation to managing the long-term climate risk, both pathways favour the climate proofing of existing infrastructure and activities, with the notable exception of a middle of the century planned revision of the localization and size of port infrastructures in APT D pathway. Ecosystem resilience and provisioning services in both of these high-investment pathways take the form of integrated port protection-energy production structures, while regulation and maintenance services (available only in APT B, but not in APT D) focus exclusively on hard coastal protection infrastructures, again in detriment of vessel technology.

Finally, the sector pathway in the Efficiency Enhancing (APT C) scenario (medium investment and medium change in policy commitment) is characterized by the flexibility of actions along the time period. The Azorean maritime transportation sector will alternate between options targeting social dialogue and awareness raising (human capital), trade diversification and climate resilient jobs (social capital), and restrictions to the development in high-risk areas and investments in refrigeration and/or cooling systems for marketable products (natural capital). The same flexibility is seen in the management of long-term disaster risks, with the pathway considering the planned revision of the localization and size of port infrastructures up to 2030, followed by the climate proofing of ports and port activities. Similarly, preparedness actions will focus on an initial stepping up of the sector's infrastructures repair and maintenance efforts to be followed by the development of new early warning systems and monitoring schemes. Regarding ecosystem resilience and services in this pathway, the maritime transportation sector will, unlike in ATP B and D, focus initially on marine friendly coastal protections and ship technology, to be followed by more classical coastal protection structures (regulation and maintenance services) some with integrated energy technology (provisioning services). One additional feature of this pathway is related to cultural services (only available in the APT C scenario), where the sector will seek to better integrate ports in urban tissue over construction of new ocean pools.

Local Knowledge options were focused on coastline protection and reflect the relevance of this issue for the Azorean maritime transport sector in the four pathways. All pathways reflect the need for continuous maintenance of infrastructures, while coastal monitoring systems are centred around the short and long term. This is potentially in line with the prospects of using adaptive management in the region (i.e., review adaptation decisions over time in line with changes in risks factors), which would facilitate incremental adaptation despite the level of investment scenarios. Additionally, such an approach can avoid locking-in the sector choices into hard infrastructures that are later difficult to revert (see **Table 1.8**).

Table 1.8. Proposed adaptation options for maritime transport in Azores.

<table>
<tr><td rowspan="7">APT A – Pathway
—
Minimum Intervention
low investment, low commitment to policy change
—
This policy trajectory assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts</td><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td colspan="2">Social dialogue for training in the port sector</td><td>Awareness campaigns for behavioural change</td></tr>
<tr><td colspan="3">Climate proof ports and port activities</td></tr>
<tr><td>Prepare for service delays or cancellations</td><td colspan="2">Intelligent Transport Systems (ITS)</td></tr>
<tr><td colspan="3">Backup routes and infrastructures during extreme weather</td></tr>
<tr><td>Marine life friendly coastal protection structures</td><td colspan="2">Combined protection and wave energy infrastructures</td></tr>
<tr><td>Strengthen coastal protection, giving priority to the maintenance</td><td>Evaluate and plan retreat of buildings/infrastructures from risk</td><td>Strengthen coastal monitoring</td></tr>
<tr><td rowspan="8">APT B – Pathway
—
Economic Capacity Expansion
high investment, low commitment to policy change
—
This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy</td><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td>Financial incentives to retreat from high-risk areas</td><td colspan="2">Insurance mechanisms for ports</td></tr>
<tr><td>Awareness campaigns for behavioural change</td><td colspan="2">Social dialogue for training in the port sector</td></tr>
<tr><td colspan="3">Increase operational speed and flexibility in ports</td></tr>
<tr><td colspan="3">Climate proof ports and port activities</td></tr>
<tr><td colspan="3">Combined protection and wave energy infrastructures</td></tr>
<tr><td colspan="3">Coastal protection structures</td></tr>
<tr><td>Strengthen coastal protection, giving priority to the maintenance</td><td>Evaluate and plan retreat of buildings/infrastructures from risk</td><td>Strengthen coastal monitoring</td></tr>
<tr><td rowspan="10">APT C – Pathway
—
Efficiency Enhancement
medium investment, medium commitment to policy change
—
This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system</td><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td>Awareness campaigns for behavioural change</td><td>Social dialogue for training in the port sector</td><td>Awareness campaigns for behavioural change</td></tr>
<tr><td>Diversification of trade using climate resilient commodities</td><td colspan="2">Climate resilient economy and jobs</td></tr>
<tr><td>Restrict development and settlement in low-lying areas</td><td colspan="2">Refrigeration, cooling and ventilation systems</td></tr>
<tr><td>Consider expansion/retreat of ports in urban planning</td><td colspan="2">Climate proof ports and port activities</td></tr>
<tr><td colspan="2">Reinforcement of inspection, repair and maintenance of infrastructures</td><td>Early Warning Systems (EWS) and climate change monitoring</td></tr>
<tr><td>Marine life friendly coastal protection structures</td><td colspan="2">Combined protection and wave energy infrastructures</td></tr>
<tr><td colspan="2">Hybrid and full electric ship propulsion</td><td>Coastal protection structures</td></tr>
<tr><td colspan="3">Integrate ports in urban tissue</td></tr>
<tr><td>Strengthen coastal protection, giving priority to the maintenance</td><td>Evaluate and plan retreat of buildings/infrastructures from risk</td><td>Strengthen coastal monitoring</td></tr>
<tr><td rowspan="8">APT D – Pathway
—
System Restructuring
high investment, high commitment to policy change
—
This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems</td><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td colspan="2">Financial incentives to retreat from high-risk areas</td><td>Insurance mechanisms for ports</td></tr>
<tr><td colspan="3">Social dialogue for training in the port sector</td></tr>
<tr><td>Restrict development and settlement in low-lying areas</td><td colspan="2">Refrigeration, cooling and ventilation systems</td></tr>
<tr><td>Climate proof ports and port activities</td><td>Consider expansion/retreat of ports in urban planning</td><td>Climate proof ports and port activities</td></tr>
<tr><td colspan="3">Backup routes and infrastructures during extreme weather</td></tr>
<tr><td colspan="3">Combined protection and wave energy infrastructures</td></tr>
<tr><td>Strengthen coastal protection, giving priority to the maintenance</td><td>Evaluate and plan retreat of buildings/infrastructures from risk</td><td>Strengthen coastal monitoring</td></tr>
</table>

Vulnerability Reduction *Disaster Risk Reduction* *Socio-Ecological Resilience* *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

1.7.1.3. Energy

In general, the energy sector in Azores is characterized by a homogenous selection of adaptation options in all adaptation policy trajectories (APTs). This indicates that the measures/ options within each adaptation class are selected regardless of the different scenario contexts.

Across all ATPs, for Vulnerability Reduction, pathways mainly rely on green jobs (human capital; all ATPs) and energy storage (natural capital; ATP C and D). Green jobs can support Azores' reliance on adaptation energy issues while serving as a form of economic diversification, reducing the dependency on the tourism sector. In contrast, public information on climate action (also human capital; all APTs) is not part of the pathways since it is assumed that there is and will be a sufficient level of public information in the island for it to pursue climate action. Energy storage is part of the pathways characterized by medium to high commitment and investment, something that is expected when considering its relevance for energy services reliability and decarbonization. The collection of forest fuel loads (natural capital; ATP C and D) is limited in Azores' Energy pathways because forest fires are considered not to be an issue in the region. In all other Vulnerability Reduction classes, adaptation measures are endorsed in the time frames where they most clearly respond to the climate risks or reflect expected sector changes. This seems to happen regardless of whether these options are dependent on technologies that are already in use today or in an initial development stage. For example, houses with low energy needs (financial capital; ATP B and D) may prove to be necessary in the short term, later evolving to smart houses in the mid and end-century time frames.

For Disaster Risk Reduction, a path is set for climate proof structures (managing long term risk; All APTs), in line with the observed violent weather events which put the energy infrastructure in Azores under stress. Towards the end of the century, the path is set to continue to have a local recovery energy outage capacity. This will allow the islands to continue to be able to recover from disasters (or malfunctions) using a proven concept instead of using a novel and conceptual architecture based on microgrids.

Evaporative cooling (managing long term risk; All APTs) is excluded from the pathways because this is a technology that has proven to be unreliable and unsuited for the islands needs and climate mainly due to the high humidity levels in Azores.

It also is a water consuming technology that can lead to constrains in water scarcity scenarios (despite the fact that the adaption option aims to review the use of technology and its standards in light of those scenarios). As seen in the tourism sector, this is a problem which causes some concern among different stakeholders.

In addition, the measure on grid connections between different islands proves to be economically unfeasible given the investment cost and lack of operational savings due to reliability constrains. It is considered more prudent to rely on backup power based on each individual island rather than depending upon a grid connection which is more vulnerable to climate hazards.

Regarding Social-Ecological Resilience, provisioning services (all ATPs) show not only a preference for proven technology but also the need to respond to the growing problem of water scarcity in some islands. Underground piping for cooling can be a difficult energy resource concept to grasp and to account for in energy planning. Waste to energy solutions (Regulating and Maintenance Services) were preferred as the islands already have significant green areas. These solutions need Combined Heat and Power (CHP) and Combined Cold Heat and Power (CCHP) to be implemented, something which is not currently in use in the islands. This is because there are only a few industries working and because the existing ones did not prefer to have them. Heated pools (cultural services), another form of CHP, were not a chosen option, thus disregarding their tourism potential to provide an off-season offer as well as to provide emergency heat sinking for power plants. Thus, educational garden plots were preferred instead.

The choice in Local Knowledge measures addresses the risks posed by extreme weather events. The second option that is chosen towards the end of the century relates with the decarbonization process and the impact of Renewable Energy Sources (RES) in the energy service quality and reliability (see **Table 1.9**).

Table 1.9. Proposed adaptation options for the energy sector in Azores.

APT A – Pathway	Short-term (up to 2030)	Mid-century (up to 2050)	End-of-century (up to 2100)
Minimum Intervention low investment, low commitment to policy change — This policy trajectory assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts	Green jobs and businesses		
	Review building codes of the energy infrastructure		
	Energy-independent facilities (generators)		
	Local recovery energy outage capacity		
	Energy efficiency in urban water management		
	Develop risk maps for the electrical infrastructure		Assess and map impacts caused in quality and power reserves

Table 1.9 (Cont.). Proposed adaptation options for the energy sector in Azores.

<table>
<tr><td rowspan="8">APT B – Pathway
—
Economic Capacity Expansion
high investment, low commitment to policy change
—
This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td colspan="3">Financial support for buildings with low energy needs</td></tr>
<tr><td colspan="3">Green jobs and businesses</td></tr>
<tr><td colspan="2">Demand Side Management (DSM) of Energy</td><td>Seawater Air Conditioning (SWAC)</td></tr>
<tr><td colspan="3">Review building codes of the energy infrastructure</td></tr>
<tr><td colspan="3">Energy efficiency in urban water management</td></tr>
<tr><td colspan="2">Biomass power from household waste</td><td>Urban green corridors</td></tr>
<tr><td colspan="2">Develop risk maps for the electrical infrastructure</td><td>Assess and map impacts caused in quality and power reserves</td></tr>
<tr><td rowspan="11">APT C – Pathway
—
Efficiency Enhancement
medium investment, medium commitment to policy change
—
This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td colspan="3">Green jobs and businesses</td></tr>
<tr><td>Small scale production and consumption (prosumers)</td><td>Risk reporting platform</td><td>Small scale production and consumption (prosumers)</td></tr>
<tr><td colspan="3">Energy storage systems</td></tr>
<tr><td colspan="3">Review building codes of the energy infrastructure</td></tr>
<tr><td>Early Warning Systems (EWS)</td><td>Grid reliability</td><td>Early Warning Systems (EWS)</td></tr>
<tr><td colspan="3">Energy efficiency in urban water management</td></tr>
<tr><td colspan="3">Biomass power from household waste</td></tr>
<tr><td colspan="3">Educational garden plots</td></tr>
<tr><td colspan="2">Develop risk maps for the electrical infrastructure</td><td>Assess and map impacts caused in quality and power reserves</td></tr>
<tr><td style="display:none"></td></tr>
<tr><td rowspan="8">APT D – Pathway
—
System Restructuring
high investment, high commitment to policy change
—
This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td colspan="3">Financial support for smart control of energy in houses and buildings</td></tr>
<tr><td colspan="3">Green jobs and businesses</td></tr>
<tr><td colspan="3">Energy storage systems</td></tr>
<tr><td colspan="3">Review building codes of the energy infrastructure</td></tr>
<tr><td colspan="3">Local recovery energy outage capacity</td></tr>
<tr><td colspan="3">Energy efficiency in urban water management</td></tr>
<tr><td colspan="2">Develop risk maps for the electrical infrastructure</td><td>Assess and map impacts caused in quality and power reserves</td></tr>
</table>

Vulnerability Reduction | *Disaster Risk Reduction* | *Socio-Ecological Resilience* | *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

Chapter

2

Balearic Islands (Spain)

SOCLIMPACT

This project has received funding from
the European Union's Horizon 2020 research
and innovation programme under
Grant Agreement No 776661

CONTENTS

The Balearic Islands at a Glance

The Balearic Islands constitute the westernmost Spanish archipelago in the Mediterranean, with a total area of 4,984 km^2 and a population of 1,150,962 inhabitants (Eurostat, 2018). The co-official languages are Catalan and Spanish. Regarding to the geographical characteristics, the highest mountain is located in Mallorca (Puig Major in the Serra de Tramuntana) and has an altitude of 1,432 m. The minimum distance separating Mallorca from Menorca is 35 km, and Ibiza is 75 km far from Valencia. The islands enjoy a mild climate with an annual average of 2,850 hours of sunshine and an average annual temperature of 18 °C. The main international airports are on Mallorca, Menorca and Ibiza. Access to the island of Formentera is only possible by ferry boat. There are seven ports with regular sea lines that host around 98,000 passengers. The islands can be reached via ferry and airplane.

The Blue Economy Sectors

- **Aquaculture**

  Production in the Blue Economy sector aquaculture is increasing, but at very low speed, and has very low importance in terms of economic weight in this region.

- **Maritime Transport**

  The passenger's ships with positive growth rates and positively growing revenues in the islands are cruise ships, a holiday activity with a rapidly growing market. However, the freight maritime transport is even more important. They provide paramount sources such as fuels, food, building material, consumer goods such as cars etc., mostly arriving from the Peninsula. The maritime transport is principally operated by the 5 most important ports of the islands (Alcúdia, Eivissa, Maó, Palma and La Savina) which are managed by "Puertos del Estado".

- **Energy**

  Regarding energy supply and electricity generation, the Spanish grid operator "Red Electrica de España" provides electricity to the islands. Moreover, two electricity subsystems of the Balearic Islands were connected in 2016 by the Majorca-Ibiza double electricity link with a submarine cable resting on the seafloor at depths of up to 800 meters. There are other interconnection projects between islands that will interconnect the islands. In 2019, the Government of the Balearic Islands has decided to meet the energy demands with 10% renewables by 2020, 35% by 2030 and 100% by 2050. Currently, 80 MW PV are installed.

- **Tourism**

  Tourism is the island's most important source of income, contributing to approximately 35% of the GDP, and closing 2019 with 16.45 million tourists. Even though arrivals have decreased 0.6%, tourist spending increased 1.4% last year to 16.51 billion euros, the highest historical value. The average stay is 6 days and the most popular time of the year is June to September. Most of the tourists come from the UK and Germany. The management of the increase in tourist arrivals along with the climate-related hazards (heat waves, flooding) are the main concerns to be addressed by the stakeholders.

2.1. Current Climate and Risks

In the Balearic Islands, the Mediterranean maritime climate predominates. Annual rainfall ranges from 350 mm to 650 mm. Usually, autumn records the highest rainfall. Temperatures are mild throughout the year, without extremes, with soft, wet winters and dry, hot summers. The winds are predominantly from the north and in winter from the south.

In Mallorca, the annual precipitation varies from one part of the island to another, between 350 mm in the south and 1,500 mm in the high mountain areas of the Tramuntana Mountains. In Minorca, the average annual rainfall is 650 mm. This figure varies depending on the year and the region of the island.

Ibiza and Formentera have a climate with high average temperatures. Rainfall is irregular and scarce, a total of 380 mm on Ibiza and 350 mm on Formentera. The predominant winds are from the west-southwest in winter and from the east in summer (see **Figure 2.1**).

CURRENT CLIMATE-RELATED RISKS

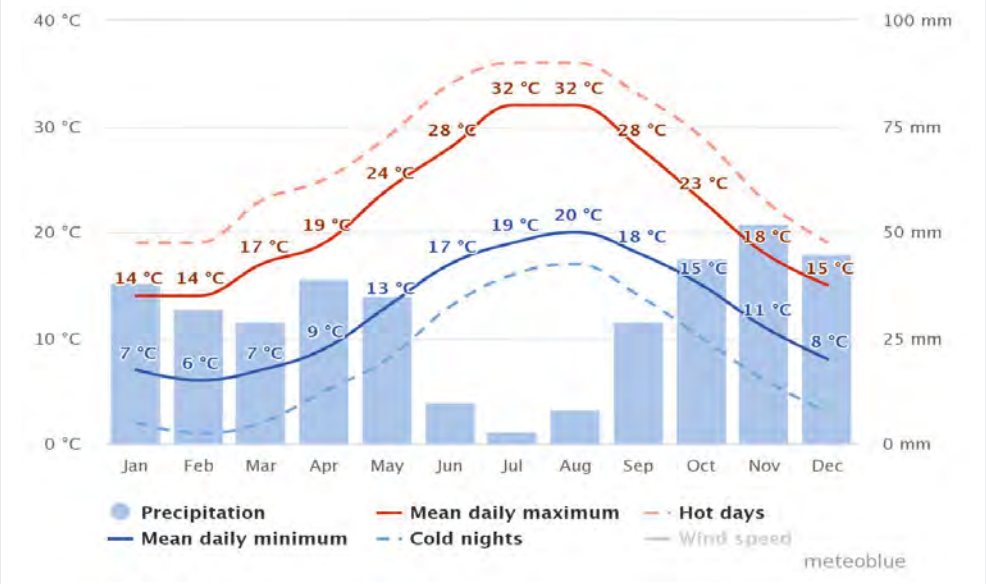
- Coastal flood High
- Water scarcity Medium

SIGNIFICANT CLIMATE EVENTS

- Flood (2018)
- Wildfire (summer 2013)

CLIMATE CHARACTERISTICS (39.63°N 2.99°E, 140m asl)

Average temperature and precipitation



Wind speed

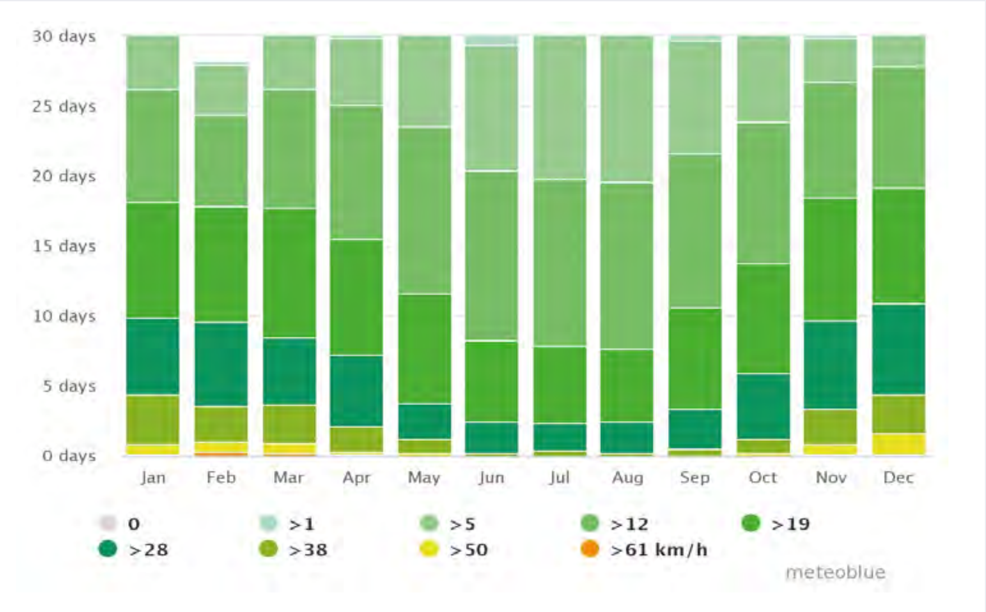
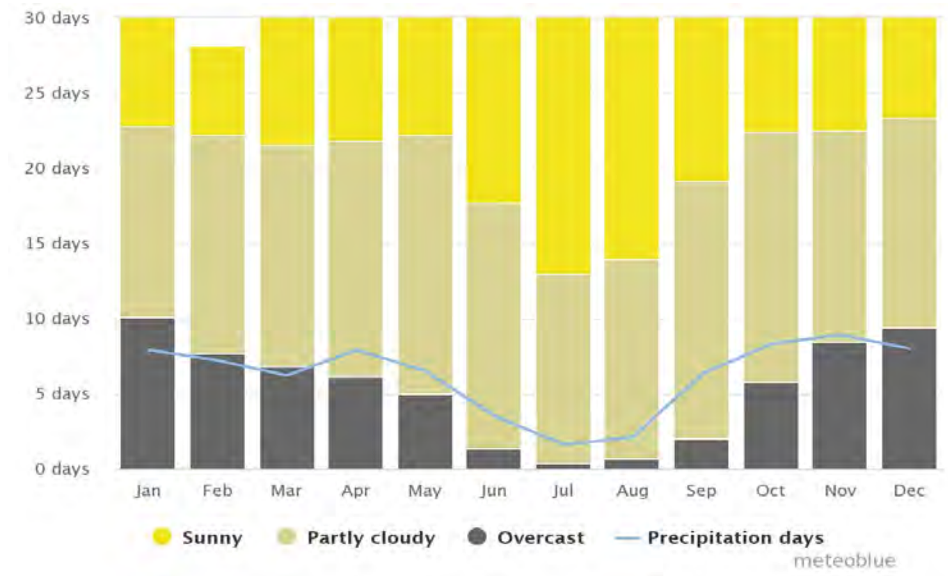


Figure 2.1. Climate factsheet.

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1 Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System). **(Continued on the next page)**

Cloudy, sunny and precipitation



Wind rose

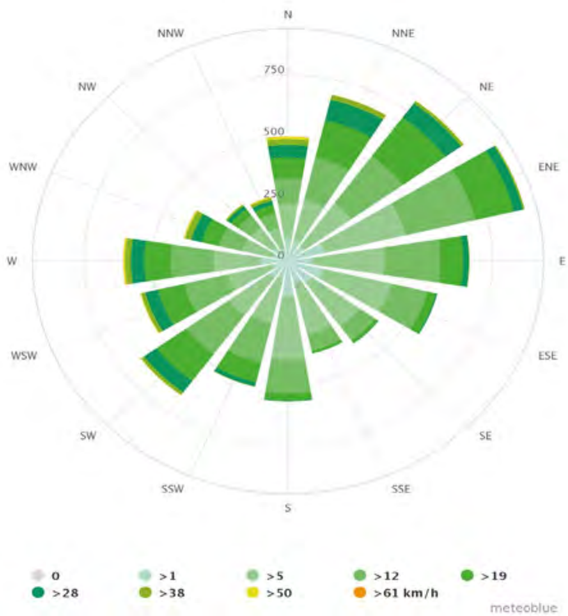


Figure 2.1 (Cont.). Climate factsheet.

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1 Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System).

2.2. Macroeconomic Projections

According to reference projections, Balearic Islands continue to grow with a 1.6% yearly rate throughout the 2015-2100 period. A main driver of growth is investments with an average yearly growth rate of 1.8% over the whole projection period (Table 2.1). While growth rates of private and public consumption are projected to decrease over time, a long-term reduction of the trade deficit also plays a key role for the sustained economic growth. This indicates a transition towards a more sustainable economy that reduces its reliance on imported consumption and increases its productive capacity through investment activity (see **Table 2.1**).

The high growth contribution of investments in the period up to 2050 is due to a high paced growth towards 2020 which counterbalances a lack of investments during the economic crisis. Throughout the 2025-2050 period, investments growth rates do not exceed overall GDP growth rates. Private consumption is projected to represent also in 2100 the largest demand component of GDP, followed by investments and public consumption (see **Figure 2.2**).

Table 2.1. Balearic Islands GDP and GDP components yearly growth rates in 2020-2100.

	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
GDP	3.1%	2.0%	1.9%	1.7%	1.6%	1.5%	1.4%	1.6%	1.6%	1.2%
Private consumption	2.3%	0.8%	0.8%	0.8%	0.7%	0.7%	0.7%	0.9%	1.1%	0.9%
Public consumption	2.8%	1.2%	1.1%	1.1%	1.0%	0.9%	0.9%	0.8%	1.0%	0.8%
Investments	3.8%	2.0%	1.8%	1.6%	1.5%	1.3%	1.2%	1.8%	1.8%	1.8%
Trade	1.4%	-1.5%	-1.7%	-1.9%	-2.1%	-2.4%	-2.9%	-3.7%	-5.2%	-5.7%

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

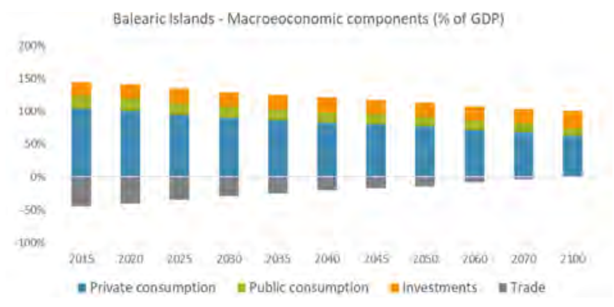


Figure 2.2. Macroeconomic components as a% share of GDP for Balearic Islands in 2015-2100.

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

The aggregated gross value added share of agriculture, fishery, manufacturing and consumer goods is projected to decline from almost 3% in 2015 to less than 2% until 2100. This observation is mainly driven by respective decreases in the gross value added shares for the consumer goods industry.

Electricity and water services are projected to contribute between 2 and 3% to total gross value added throughout the projection period.

Total tourism activities are projected to provide rather stable contributions to total gross value added throughout the projection period. Starting from more than 18% in 2015, the respective shares decline slightly to less than 17% in 2100[1] (see **Table 2.2** and **Figure 2.3**).

2.2.1. The Sectoral Projections

The Balearic Islands', economy remains a service-led economy throughout the 2015-2100 period with an increasing contribution of other market services, construction services and transport services. Whereas declining shares in overall gross value added are projected for accommodation and food services as well as non-market services, both sectors are still projected to provide significant contributions (more than 27%) to total gross value added in 2100.

[1] The share of tourism in GDP is calculated via the tourism satellite account (TSA) matrices of 2015, assuming that the same shares that indicate the contribution of tourism to the productions of tourism-related sectors (such as the accommodation and food services, transport services, travel agency and related activities, cultural and recreational activities) remain throughout the 2015-2100 period.

Table 2.2. Sectoral contribution as a% share of total gross value added for Balearic Islands in 2015-2100.

GVA% shares	2015	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
Agriculture	1.1%	1.0%	1.0%	1.0%	0.9%	0.9%	0.9%	0.9%	0.8%	0.8%	0.7%
Fishery	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	0.0%
Manufacturing	0.2%	0.2%	0.2%	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Consumer goods	1.6%	1.3%	1.2%	1.2%	1.1%	1.1%	1.1%	1.1%	1.0%	0.9%	0.8%
Electricity	2.2%	2.1%	2.1%	2.0%	2.0%	2.0%	1.9%	1.9%	1.8%	1.7%	1.6%
Water	0.7%	0.7%	0.7%	0.6%	0.6%	0.6%	0.6%	0.6%	0.5%	0.5%	0.5%
Construction	8.6%	9.5%	9.6%	9.7%	9.8%	9.9%	10.0%	10.1%	10.3%	10.5%	14.7%
Water transport	1.6%	1.5%	1.5%	1.5%	1.4%	1.4%	1.4%	1.3%	1.3%	1.2%	1.1%
Other transport	4.5%	4.5%	4.6%	4.7%	4.8%	4.9%	5.0%	5.2%	5.5%	5.8%	5.9%
Accommodation & food services	18.1%	17.6%	17.5%	17.4%	17.3%	17.2%	17.2%	17.1%	16.9%	16.7%	15.8%
Travel agency & related activities	1.5%	1.4%	1.3%	1.3%	1.2%	1.2%	1.2%	1.2%	1.1%	1.0%	0.9%
Recreational services	0.6%	0.6%	0.6%	0.5%	0.5%	0.5%	0.5%	0.5%	0.4%	0.4%	0.4%
Other market services	45.4%	45.8%	46.1%	46.3%	46.5%	46.7%	46.8%	46.9%	47.2%	47.4%	45.5%
Non-market services	13.9%	13.7%	13.6%	13.5%	13.4%	13.4%	13.3%	13.2%	13.0%	12.8%	12.1%

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

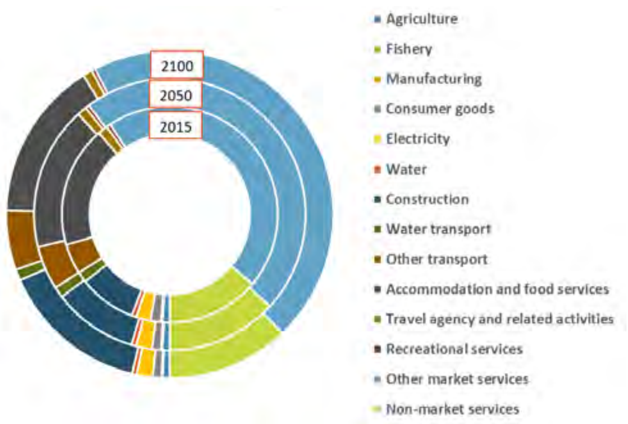


Figure 2.3. Sectoral value added as a% share to total GVA for Balearic Islands in 2015, 2050 and 2100.

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

2.2.2. Employment

The service-led economic growth brings positive effects to the labour market with unemployment projected to fall from almost 14% in 2015 to slightly less than 7% in 2100. The contribution of each sector to total employment depends on the labor intensity of the sector. The biggest employing sectors are non-market and other market services as well as accommodation and food services. Recreational services and construction services also feature significant employment shares throughout the 2015-2100 period.

Tourism is largest employer of the Blue Growth sectors under analysis, particularly due to the high labor intensity of accommodation and food services. The lowest contribution to overall employment among Blue growth sectors is attributed to the fisheries sector (see **Figure 2.4** and **Table 2.3**)

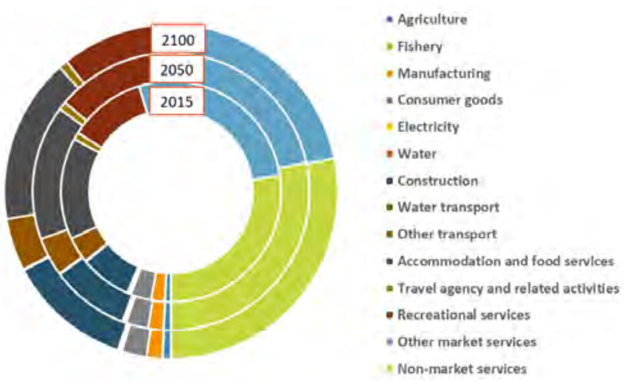


Figure 2.4. Sectoral employment as a% share of total for Balearic Islands in 2015, 2050, 2100.

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

Table 2.3. Unemployment rate for Balearic Islands in 2015-2100.

	2015	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
Unemployment rate	13.8%	10.4%	9.0%	8.1%	7.7%	7.6%	8.0%	7.9%	7.3%	6.3%	6.9%

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

2.3. Climate Change Outlook

Climate hazards indicators represent the entry point to understand the climate change exposure of the blue economy sectors. The indicators have been computed for RCP2.6 (low emission scenario) and RCP8.5 (high emission scenario) and for different horizon times namely: a reference period (1965-2005), mid-century (2046-2065) and end of century (2081-2100). Main source of climate projections (future climate) for the Balearic Islands is MED-CORDEX ensemble (regional scale of Mediterranean area) and CMIP5 Ensemble (global scale) even if other model sources were applied when required, depending on available scales. Results are presented in form of maps, tables or graphs and only when the information shows an interesting outcome.

2.3.1. Tourism

2.3.1.1. Seagrass evolution

Posidonia Oceanica and Zostera are foundation species in Mediterranean waters. Foundation species have a large contribution towards creating and maintaining habitats that support other species. First, they are numerically abundant and account for most of the biomass in an ecosystem. Second, they are at or near the base of the directional interaction networks that characterize ecosystems. Third, their abundant connections to other species in an ecological network mostly reflect non-trophic or mutualistic interactions, including providing structural support for other species, significantly altering ecosystem properties to [dis]favor other species, altering metabolic rates of associated species, and modulating fluxes of energy and nutrient flow through the system.

Seagrasses are the main habitat for coastal marine ecosystems. They provide different services like sediment retention (and thus clearer waters), coastal protection (in front of marine storms), shelter for marine organisms, etc. Therefore, the state of seagrasses is a convenient proxy for the state of coastal environment.

Three species are located in the coasts of Balearic Islands: Cymodocea, Zostera and Posidonia, which is the most represented species. The results of RCP8.5 projections indicate a complete disappearance of Zostera from mid-century, and for Posidonia, a loss of 35% could be observed at end of century (see **Figure 2.5**).

2.3.1.2. Beach flooding and related losses

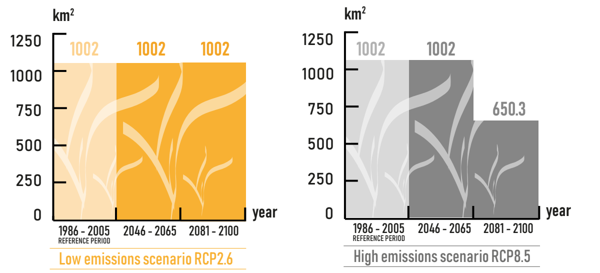


Figure 2.5. Seagrass evolution.

Source: SOCLIMPACT Deliverable Report - D4.4e. Report on estimated seagrass density.

One of the consequences of an increase in the mean sea level will be the flooding of coastal areas. This includes sand beaches, which are the main asset for tourism activities in most of the European islands. Therefore, estimating the potential risk of beach loss due to climate change is of paramount importance for the economy of those islands (see **Figure 2.6** and **Figure 2.7**).

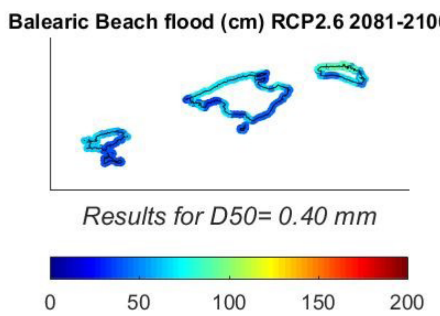


Figure 2.6. Projected extreme flood level (in the vertical, in cm) at beach locations with respect to the present (1986-2005) mean sea level values averaged for the islands under scenario RCP2.6. Own elaboration based on global and regional simulations.

Source: SOCLIMPACT Deliverable Report - D4.4d on the evolution of beaches.

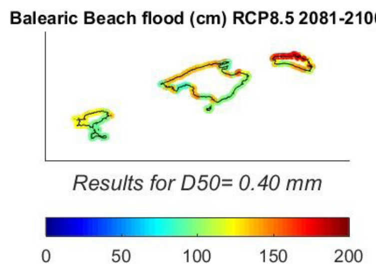


Figure 2.6 (Cont.). Projected extreme flood level (in the vertical, in cm) at beach locations with respect to the present (1986-2005) mean sea level values averaged for the islands under scenario RCP8.5. Own elaboration based on global and regional simulations.

Source: SOCLIMPACT Deliverable Report - D4.4d. Report on the evolution of beaches.

The 95th percentile of the flood level averaged was selected as an indicator of interest. The values are presented as anomalies with respect to the present mean sea level at beach location (i.e, including the median contribution of runup).

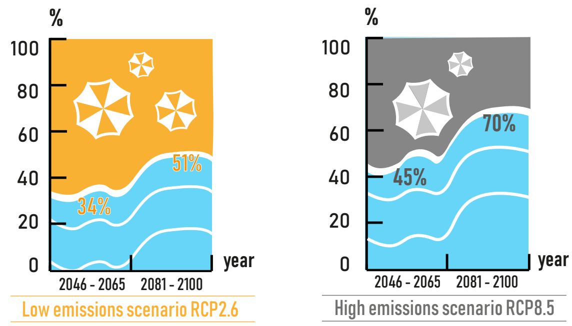


Figure 2.7. Beach reduction % (scaling approximation).

Source: SOCLIMPACT Deliverable Report - D4.4d. Report on the evolution of beaches.

An increase is expected being larger at the end of the century under scenario RCP8.5. Under mean conditions, we find that, at end of century, the total beach surface loss ranges from ~45 % under scenario RCP2.6 to ~70 % under scenario RCP8.5.

2.3.1.3. Fire Weather Index (FWI)

The FWI system provides numerical non-dimensional ratings of relative fire potential for a generalized fuel type (mature pine stands) based solely on weather observations. FWI is part of the Canadian Forest Fire Danger Rating System established in Canada since 1971 (van Wagner, 1987). Furthermore, since 2007, FWI has been adopted at the EU level and used in a harmonized way throughout Europe by the European Forest Fire Information System (EFFIS) of the Copernicus Emergency Management Service (since 2015).

It is selected for exploring the mechanisms of fire danger change for the islands of interest, as it has been proved to adequately perform for several locations, including the Mediterranean basin. The index was calculated for the fire season (defined from May to October) over the Mediterranean for all models, scenarios and periods.

For the archipelago of Baleares, N = 49 grid cells were retained from the model's domain. In the following figure, the ensemble means and the uncertainty are presented for all periods and RPCs. It seems that under RCP2.6, the index slightly increases at the middle of the century, while it returns to present levels towards the end of the century. On the other hand, under RCP8.5 there is an increased fire danger that exceeds 30 % at the end of the century.

In any case, the fire danger for Baleares is among the lowest of the Mediterranean islands, with a normalized FWI in the low category for fire danger and only the central areas of Mallorca reach medium fire danger by the end of the century (see **Figure 2.8**).

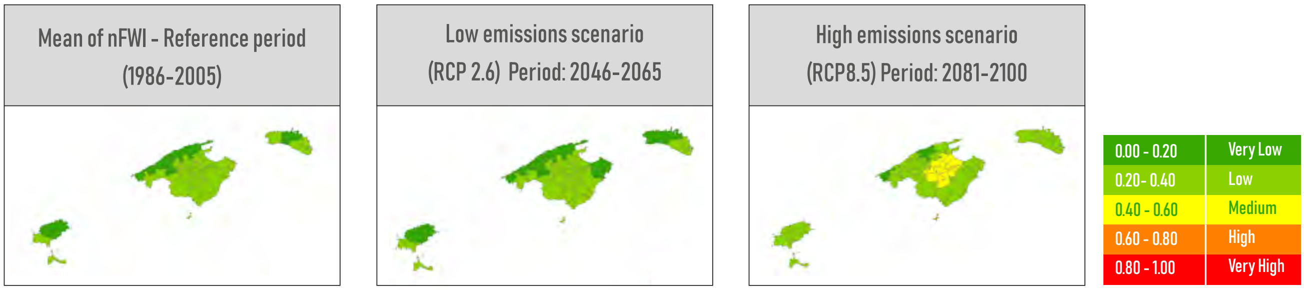


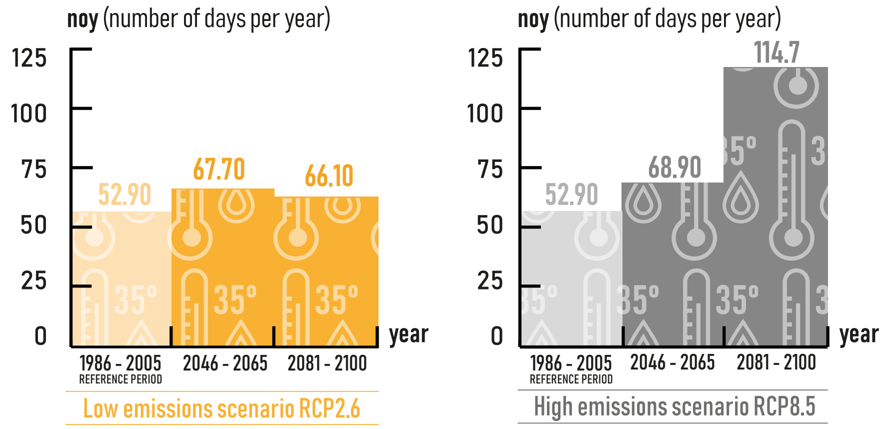
Figure 2.8. Fire Weather Index (EURO-CORDEX) with the color associated to the class of hazard.

Source: SOCLIMPACT Deliverable Report - D4.4c. Report on potential fire behaviour and exposure.

2.3.1.4. Humidex

For the assessment of climate hazard on heat related impacts of climate change on human health, the humidity index (Humidex) (Masterton and Richardson, 1979) has been used. Humidex value is an equivalent temperature, which express the temperature perceived by people (the one that the human body would feel), given the actual air temperature and relative humidity. As a more representative indicator for the assessment of inhabitants' and tourists' hazard on heat related climate change impacts, the Number of Days with Humidex greater than 35 °C was selected. From the above classification, a day with Humidex above 35 °C describes conditions from discomfort to imminent danger for humans.

For the archipelago of Baleares, N = 49 grid cells were retained from the models domain. In the following figure the ensemble mean and the uncertainty are presented for all periods and RPCs. It is found that the number of days above discomfort threshold would be double under RCP8.5 by the end of the century (see **Figure 2.9**).



HUMIDITY	INDEX-DISCOMFORT LEVEL
<29°C	comfortable
30-34°C	some discomfort
35-39°C	discomfort; avoid intense exertion
40-45°C	great discomfort; avoid exertion
46-53°C	significant danger; avoid any activity
>54°C	imminent danger; heart stroke.

Figure 2.9. Number of days per year with Humidex > 35 °C (Euro-CORDEX).
Source: SOCLIMPACT Deliverable Report - D4.3*. Atlases of newly developed indexes and indicator.*

2.3.1.5. Length of the window of opportunity for vector-borne diseases

Vector Suitability Index for Aedes Albopictus (Asian Tiger Mosquito)

Climate change can influence the transmission of vector-borne diseases (VBDs) through altering the habitat suitability of insect vectors. This is mainly controlled by increases of ambient air temperature and changes in the hydrological cycle. Thus, we explore if potential changes to meteorological conditions can affect the distribution of the Asian tiger mosquito (Aedes albopictus). Asian tiger mosquito is native to the tropical and subtropical areas of Southeast Asia; however, in the past few decades, this species has spread to many countries through the international transport of goods and increased travel (Scholte and Schaffner, 2007). It is of great epidemiological importance since it can transmit viral pathogens and infectious agents that cause chikungunya, dengue fever, yellow fever and various encephalitides (Proestos *et al.,* 2015).

The multi-criteria decision support vector distribution model of Proestos *et al.* (2015) has been employed to estimate the regional habitat suitability maps. This is based on extending previous work on the environmental/climatic factors affecting the life cycle of the Asian tiger mosquito (Waldock *et al.,* 2013; Proestos *et al.*, 2015). The mosquito habitat suitability model combines seven meteorological indices based on field observations, extensive literature review and expert knowledge.

The Balearic Islands in the western part of the Mediterranean offer a slightly less favorable environment for Aedes Albopictus (HSI values of 66.1). The most suitable regions are the island of Menorca and the northern parts of Mallorca. Under future climatic conditions, the islands will remain in the medium suitability regime on average under the RCP2.6 pathway. On the contrary, under pathway RCP8.5, habitat suitability index values are projected to be in the low suitability regime (see **Figure 2.10**).

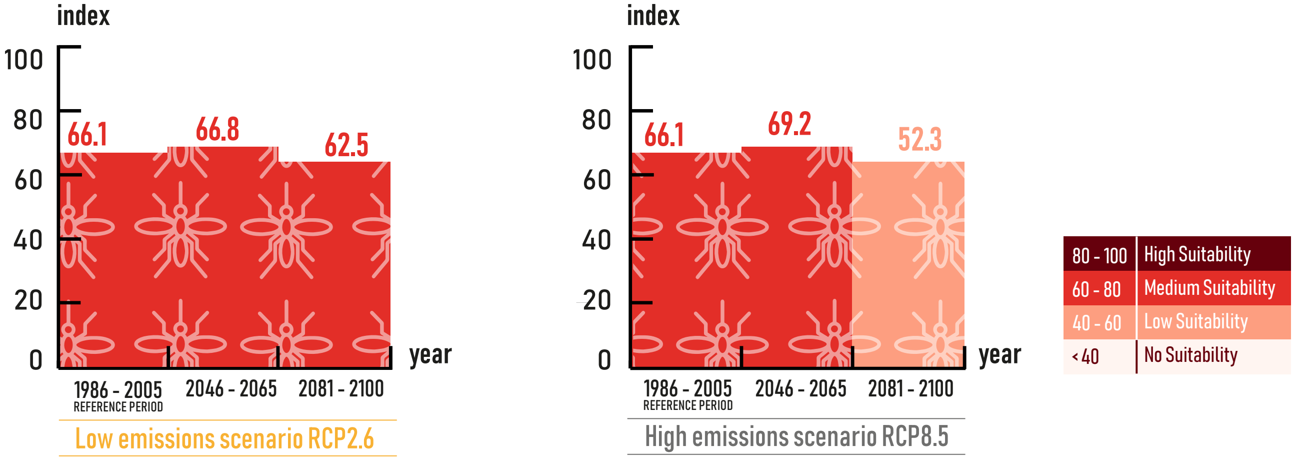


Figure 2.10. Habitat Suitability Index (HSI). [80-100: High Suitability; 60-80 Medium Suitability; 40-60 Low Suitability; <40 No Suitability].
Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed hazard indexes and indicators.

2.3.2. Aquaculture

2.3.2.1. Extreme Wave Return Time

Changes in currents and waves cause decreased flushing rates (shellfish) and salinity changes, leading to accumulation of waste under cages, stock loss, and damage to facility/structure. Under this scenario, there is a need to invest in stronger constructions and higher insurance costs. In order to analyse these changes, return times for a threshold of 7 m significant wave height (hs) were computed. This significant height has been identified by stakeholders as the critical limit for severe damages to assets at sea. Return times can be related to the payback times of investments and help assess potential economic losses and economic sustainability. In the future, under RCP8.5. (far future), the extreme wave return time will increase all around the islands (see **Figure 2.11**).

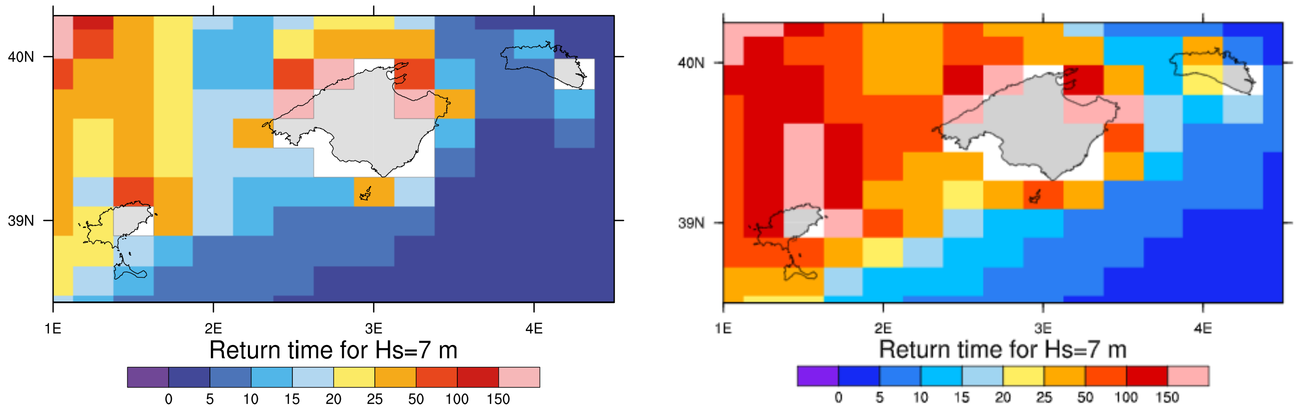


Figure 2.11. Extreme wave return under present climate and under RCP8.5 (far future).
Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed hazard indexes and indicators with Appendices.

2.3.2.2. Annual Mean Significant Wave Height (AMSH)

The Annual Mean Significant Wave Height was selected as a relevant indicator of the average stress for aquaculture infrastructures. For Balearic Islands, a decrease of annual mean significant wave height could be observed under RCP8.5 at the end of century (see **Figure 2.12**).

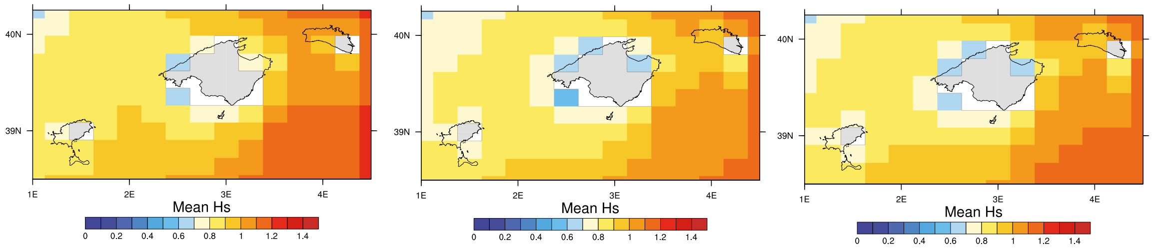


Figure 2.12. Annual Mean Significant Wave Height for present conditions (left) and projections under scenario RCP8.5 for near future (2046-2065) and far future (2081-2100).

Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed hazard indexes and indicators.

2.3.3. Energy

2.3.3.1. Renewable energy productivity indexes

A series of indicators related to renewable energy productivity is presented. The selected indicators are wind and photovoltaic (PV) energy productivity, as well as the frequency and duration of low-productivity periods, termed energy droughts (Raynaud *et al.*, 2018), as a measure of the variability of these sources. The productivity and variability of these renewable energy sources will depend on climate. The possibility of reduced productivity due to climate change poses a risk to the energy generation, if it is based on these renewable energy sources. Also, a possible increase in the frequency and duration of solar and wind energy droughts will require an increase in storage and backup sources.

Among the different renewable energy sources, solar PV and wind energy have been selected, as they are (and very likely will be) the main renewable energy sources, due to their degree of technological development and their comparatively low cost. In order to consider a marine energy source, offshore wind energy is included, in addition to onshore wind energy.

A general decrease can be observed for every scenario and period, being the 2081-2100 period in RCP8.5 the one with the highest decrease. A noticeable maximum decrease is observed between Mallorca and Ibiza in this latter case, while over land the decrease is maller in absolute terms, but higher in relative terms as Wprod is systematically lower (see **Figure 2.13**).

The future decrease in Wprod is found for both land and maritime regions and both emissions scenarios, although with differences in the magnitude. RCP8.5 is clearly the scenario where a higher decrease in productivity is expected. It is worth noting that RCP2.6 seems to recover from the decrease by the end of the 21st century, in contrast to RCP8.5. The decreases are higher in relative terms over land (up to 13%).

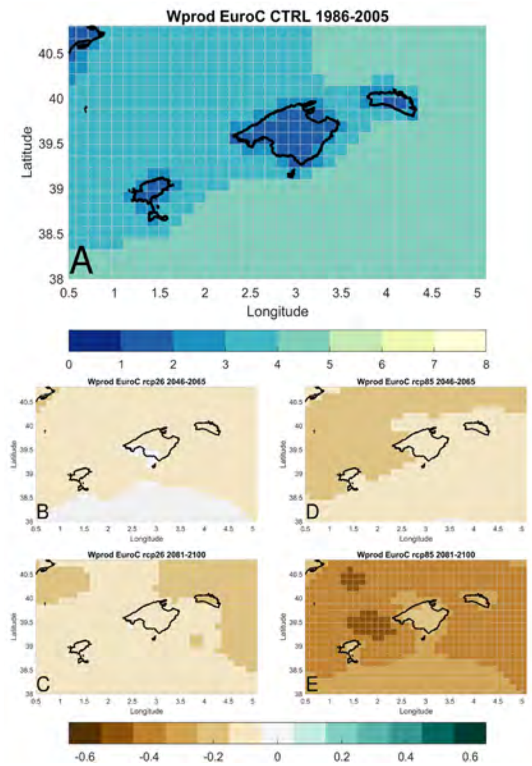


Figure 2.13. E2: Panel A: Yearly mean wind energy productivity [10^3 kWh/kW] for the control time period (1986-2005). Panels B - C: Changes in yearly mean wind energy productivity in the RCP2.6 scenario for periods 2046 - 2065 and 2081 - 2100 with respect to the control. Panels D - E: As for panels B - C, but for the RCP8.5 scenario.

Source: SOCLIMPACT Deliverable D4.4a - Report on solar and wind energy.

2.3.4. Maritime Transport

2.3.4.1. Sea Level Rise

Sea Level Rise (SLR) is one of the major threats linked to climate change. It would induce permanent flooding of coastal areas with a profound impact on society, economy and environment. Moreover, an increase in the mean sea level would result in a larger impact of coastal storms with the consequent increase of risk. The results are presented in terms of mean sea level rise. For Balearic Islands, the SLR ranges from 24.92 cm (RCP2.6) to 65.86 cm (RCP8.5) at the end of the century (see **Figure 2.14**).

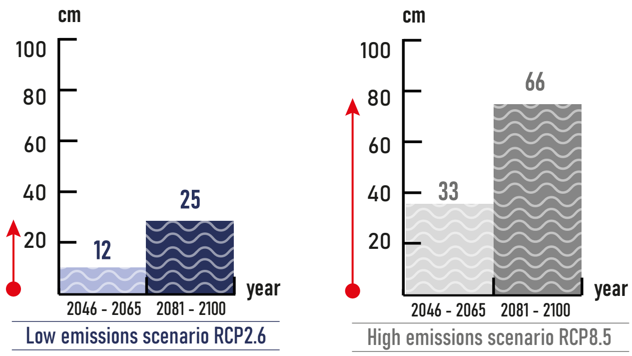


Figure 2.14. Mean sea level rise (in cm) with respect to the reference period (1986-2005). Own elaboration based on global and regional simulations.

Source: SOCLIMPACT Deliverable D4.4b - Report on storm surge levels.

2.3.4.2. Storm surge extremes

Storm surge events, characterized by positive extreme sea levels and mechanically forced by atmospheric pressure and wind are mainly responsible for coastal flooding, especially when combined with high tides.

To date, the only ensemble populated with enough number of members to compute meaningful statistics on climate projections is the one produced for the Mediterranean by Lionello *et al.* (2017). This ensemble consists on 6 simulations run with the HYPSE model at 1/4° of spatial resolution and forced by the high-resolution wind fields from the MedCORDEX ensemble which in turn is nested into CMIP5 global simulations. The simulations are run for the period 1950-2100, thus covering the historical period as well as the whole 21st century. Complementary, the ensemble includes three hindcast simulations that are used to establish present reference levels. Storm surge could decrease amount 10 % under RCP8.5 (far future) (see **Figure 2.15**).

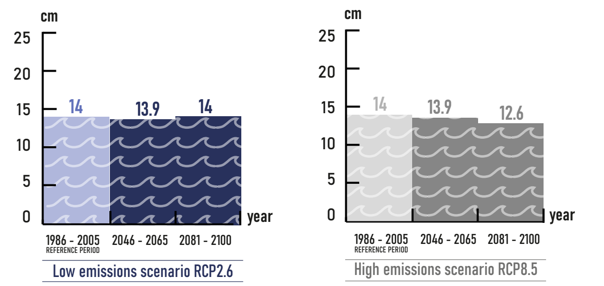


Figure 2.15. 99th percentile of atmospherically forced sea level (in cm) averaged for the hindcast period, the near future (2046-2065) and the far future (2081-2100) under scenarios RCP2.6 (with scaling approximation) and RCP8.5, relative change in brackets.

Source: SOCLIMPACT Deliverable D4.4b - Report on storm surge levels.

2.3.4.3. Frequency of extreme high winds (Wind Extremity Index – NWIX98)

The wind extremity index NWIX98 is defined as the number of days per year exceeding the 98th percentile of mean daily wind speed. This number decreases in the far future with a strongest value under RCP8.5 (- 27 %) (see **Figure 2.16**).

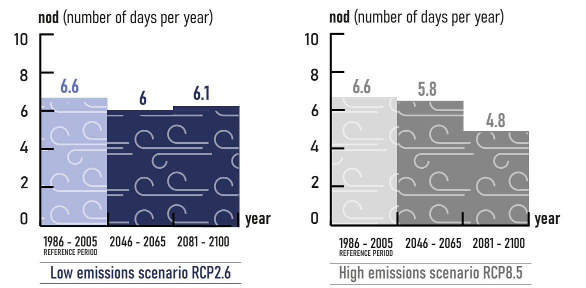


Figure 2.16. Wind Extremity Index (NWIX98). Ensemble mean of EURO-CORDEX simulations.

Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed indexes and indicator.

2.3.4.4. Wave extremes (99th percentile of significant wave height averaged)

Marine storms can have a negative impact on maritime transport, coastal-based tourism and aquaculture, among other activities. To illustrate this impact, the 99th percentile of significant wave height averaged has been chosen. A decrease in the extreme wave height is found being larger under scenario RCP8.5 as illustrated in the following map (see **Figure 2.17**).

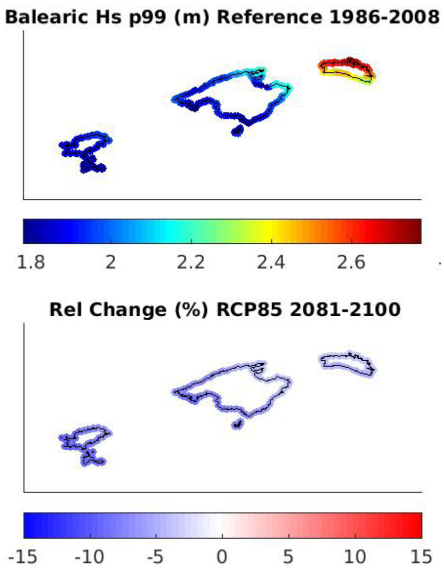


Figure 2.17. The 99th percentile of significant wave height averaged for the reference period and the relative change for the RCP8.5. MED-CORDEX and Global simulations produced by Hemer *et al.* (2013).

Source: SOCLIMPACT Deliverable D4.4b - Report on storm surge levels.

2.4. Risk Assessment

2.4.1. Tourism

2.4.1.1. Loss of attractiveness due to marine habitats degradation

The Balearic Islands are the most exposed islands. In addition, RCP8.5 distant future shows a progress in heating relatively higher than other islands, meaning a strong threat to their relatively susceptible Posidonia meadows.

Balearic's risk regarding seawater heating rests on the high natural exposure represented by the surface of their Posidonia meadows and the size of their marine habitat-based tourist activity, representing the 25% of the risk. Of course, as Posidonia surface must be preserved, and the flow of tourists maintained, resilience against this risk should be achieved through strengthening mainly the potential to successfully substitute marine based demand for demand for other tourist products, which need to be properly developed and commercialised. The Archipelago has a wide range of other natural and cultural resources and technical and financial capabilities to go forward this way and is already working on it. The eradication of other pressures on Posidonia meadows, as sewage and coastal infrastructures, is capital for keeping this risk under control, as it has been outlined by recent research.

The mentioned advantages and disadvantages of the Balearic Islands are depicted in the next figures. The further the criteria or sub-criteria is located from the centre of the graph, the more it affects the risk (see **Figure 2.18** and **Figure 2.19**).

The AHP method (see Appendix F) proved to be appropriate, firstly, for dealing with the hierarchical nature of the impact chain and, secondly, for using expert judgements to assess the comparative risk for the islands over a large number of indicators (sub-criteria). Because the AHP method determines a ranking of the islands, it can provide decision-makers with relative values but not with absolute values.

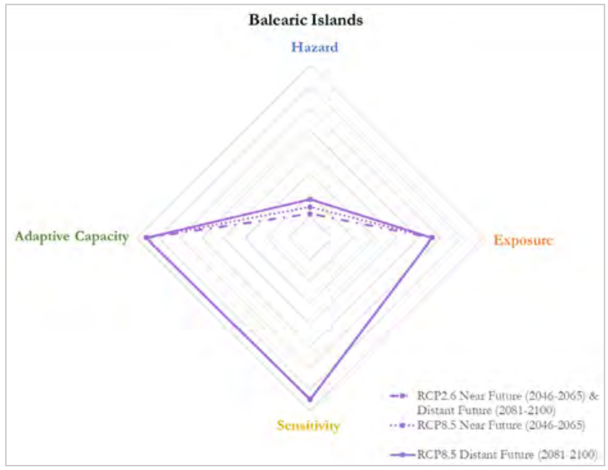


Figure 2.18. Global weights of each criteria and sub-criteria in the final score.

Source: SOCLIMPACT Deliverable Report - D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

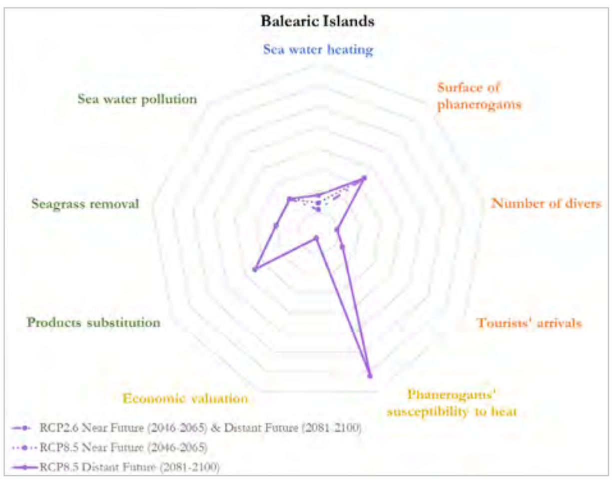


Figure 2.19. Global weights of each criteria and sub-criteria in the final score.

Source: SOCLIMPACT Deliverable Report - D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

2.4.1.2. Loss of comfort due to a decrease in thermal comfort

According to the results, the islands show some disadvantages in the criterion Sensitivity and Exposure, which contribute 39.7 % and 32.2 %, respectively, to the total risk. In the former stands out the importance of the heat-sensitive activities, while the latter can be explained by the high amount of tourists that arrives to the islands each year (see **Figure 2.20** and **Figure 2.21**).

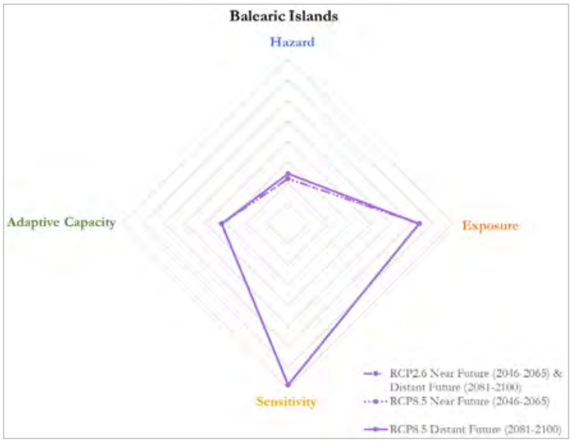


Figure 2.20. Global weights of each criteria and sub-criteria in the final score.

Source: SOCLIMPACT Deliverable Report - D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

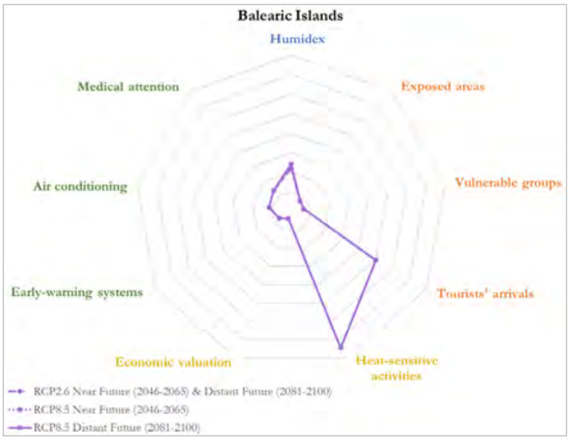


Figure 2.21. Global weights of each criteria and sub-criteria in the final score.

Source: SOCLIMPACT Deliverable Report - D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

The mentioned advantages and disadvantages of Balearic Islands are depicted in the next figure. The further the criteria or sub-criteria is located from the centre of the graph, the more it affects the risk.

The AHP method proved to be appropriate, firstly, for dealing with the hierarchical nature of the impact chain and, secondly, for using expert judgements to assess the comparative risk for the islands over a large number of indicators (sub-criteria). Because the AHP method determines a ranking of the islands, it can provide decision-makers with relative values but not with absolute values.

2.4.1.3. Loss of attractiveness due to increased danger of forest fires in touristic areas

Forest fires are considered as an important parameter for the attractiveness of tourist destinations, especially in the Mediterranean area. Severe episodes were met in Algarve (Portugal) and Greece (Athens area) in the recent period, threatening the tourist season.

The Balearic Islands maintain the same dynamic as for the reference period (1986-2005), for both near future (2046-2065) and distant future (2081-2100) in both scenarios RCP2.6 (Ambitious Mitigation Policies) and RCP8.5 (Business as usual), with an overall low risk of forest fires. The reason for this is that, although the exposure and vulnerability levels are medium, fire danger remains low over time (hazard). Compared to the other archipelagos/islands, it is one of the least at risk of forest fires in the future (see **Figure 2.22** and **Figure 2.23**).

Figure 2.22. Risk score for the reference period.

Source: SOCLIMPACT Deliverable Report - D4.5. Comprehensive approach for policy makers.

Figure 2.23. Risk score at the end in the distant future (2081-2100) under RCP2.6 (Ambitious Mitigation Policies) and RCP8.5 (Business as usual).
Source: SOCLIMPACT Deliverable [Report - D4.5]. Comprehensive approach for policy makers.

Maritime Transport

Ports are vulnerable nodes of maritime transport as they are strongly affected by rising sea-levels, which in turn affect port facilities and increase the risk of flooding. For the historical reference period, the risk value for Balearic Islands was 0.326 (low risk). The greatest contribution to the overall risk comes from the low adaptive capacity because of the small number of harbour alternatives and low percentage of renewables in the island. Since the contribution of renewables is expected to increase under RCP2.6 while the contribution of exposure and hazard indicators is more or less the same, for the middle of the current century the risk under this scenario is expected to decrease to a value of 0.281. By the end of the century, the risk for maritime transport disruption for the Balearics is expected to further decrease (0.264). For the "business-as-usual" RCP8.5, the risk is expected to slightly increase (values of 0.331-0.344), as a result of the meteorological hazards (mainly extreme winds and mean sea level rise) and smaller contribution of renewable energy (see **Table 2.4**).

Table 2.4. Summary of present and future risk of isolation due to maritime transport disruption for each island and scenario based on the Impact Chain operationalization.

Risk value per island	Historical reference	RCP2.6 MID	RCP2.6 END	RCP8.5 MID	RCP8.5 END
Cyprus	0.241	0.210	0.218	0.258	0.292
Crete	0.229	0.208	0.201	0.257	0.282
Malta	0.376	0.347	0.335	0.395	0.414
Corsica	0.220	0.194	0.194	0.243	0.273
Canary Islands	0.336	0.292	0.250	0.346	0.341
Balearic Islands	0.326	0.281	0.264	0.331	0.344

Categorization:

0.00 – 0.20 Very low	0.20 – 0.40 Low	0.40 – 0.60 Medium	0.60 – 0.80 High	0.80 – 1.00 Very high

Source: SOCLIMPACT Deliverable [Report – D4.5]. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

2.5. Impacts on the Blue Economy Sectors

2.5.1. Tourism (Non-Market Analysis)

In order to analyse the reactions of tourists to the impacts of climate change and the preferences for adaptation policies, several hypothetical situations were posed to 253 tourists visiting Balearic Islands whereby possible CC impacts were outlined for the island (i.e., beach erosion, infectious diseases, forest fires, marine biodiversity loss, heat waves, etc.) (see **Figure 2.24**).

Firstly, tourists had to indicate whether they would keep their plans to stay on the island or find an alternate destination if the impact had occurred, which allows predictions of the effects on tourism arrivals to be made for each island. Secondly, tourists were asked to choose between various policy measures funded through an additional payment per day of stay – the tourists' choices being an expression of their preferences for attributes/policies. To estimate the results, the conditional logit model was run by using the Stata software.

In general, data confirms that tourists are highly averse to risks of infectious diseases becoming more widespread (98.40% of tourists would change destination). Moreover, they are not willing to visit the islands is beaches largely disappear (91.30%) or if the temperature becomes uncomfortably hot to them (87.40%). On the other hand, policies related to coastal infrastructures protection (1.2€/day), infectious diseases prevention (1€/day), water supply reinforcement (1€/day), and heat waves protection (1€/day) are the most valued, on average, by tourists visiting these islands.

Although climate change impacts are outside the control of tourism practitioners and policy-makers, they can nevertheless utilise this knowledge to improve the predictability of the effect of certain adaptation policies and risk management strategies, and develop their plans accordingly (see **Figure 2.25**).

The impact of increased temperatures and heat waves on hotels' prices and revenues

In order to assess how the variation in temperature impacts on the tourism sector through changes in tourism demand our research question was: "How do increasing temperatures (and heat waves) impact prices and, more in general, expenditure of tourists?" Arguably, when temperatures grow, tourists adjust their behaviour: they might switch destination, or they might stay longer or shorter depending on their attitudes and preferences. In turn, all these changes modify the market equilibrium, pushing tourism companies to adjust their prices to re-establish the equilibrium between demand and supply. The change in demand and the change in price determine the change in tourism expenditure which is, from the destination's perspective, tourism revenue.

We monitored current weather conditions posted on several weather forecast providers and daily prices posted on [Booking.com]() by hotels. We then estimated the link between daily temperature and daily price, controlling for all the other factors affecting prices. We finally applied these estimates to the increase in the number of days with excessive temperature projected for the future in two scenarios (RCP2.6 and RCP8.5) and in two time horizons (near future, about 2050; distant future, about 2100).

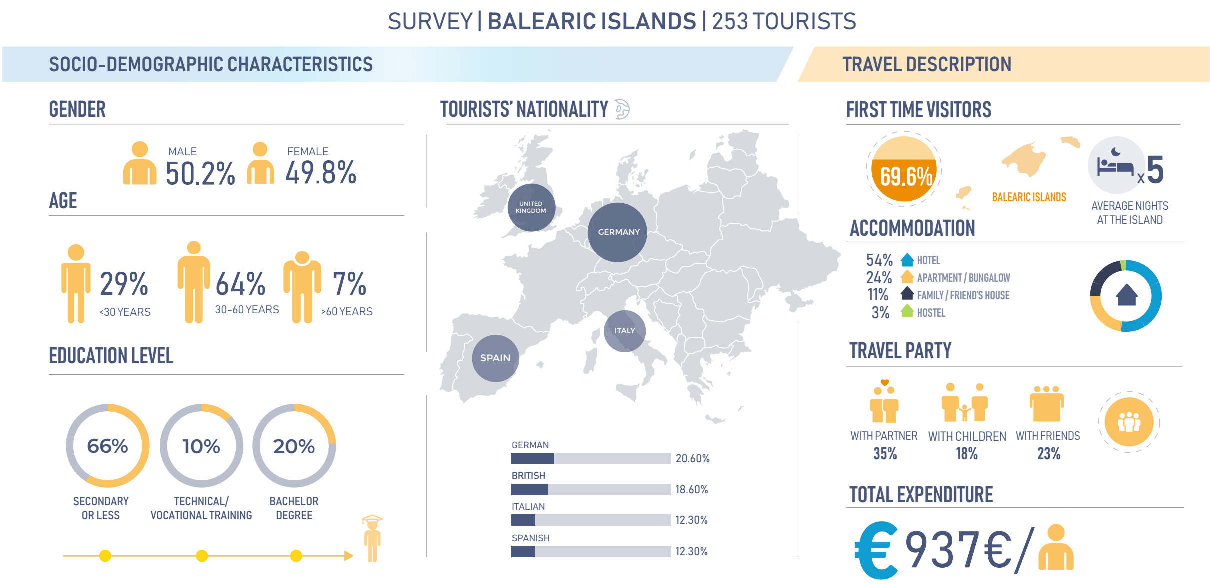


Figure 2.24. Socio-economic characteristics and travel description: tourists visiting Balearic Islands.
Source: SOCLIMPACT Deliverable [Report D5.5](). Market and non-market analysis.

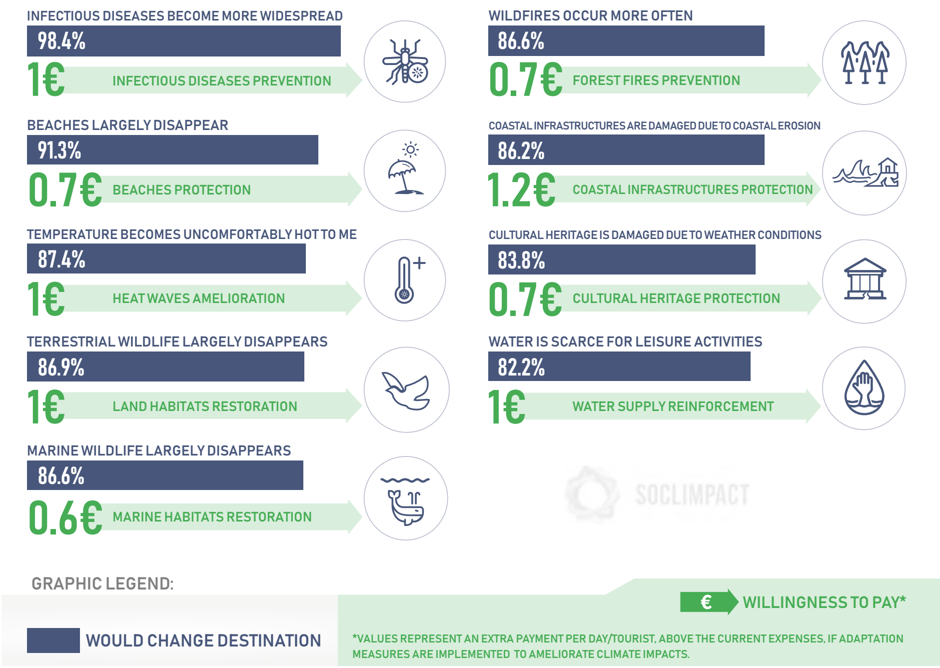


Figure 2.25. Tourists' response to climate change impacts and related policies: tourists visiting Balearic Islands.
Source: SOCLIMPACT Deliverable Report - D5.5. Market and non-market analysis.

Among the different indicators linked to thermal stress, we focus on two: the number of days in which the temperature is above the 98th percentile and the number of days in which the perceived temperature is above 35 °C. Although the impact for both indices was computed, in this document we only report the second one (named Humidex) because it is the most intuitive and because human thermal stress is more related to the absolute value of the temperature than its deviation from some pre-determined distribution. We assumed that thermal stress appears when the perceived temperature grows above 35 °C.

As thermal stress is delimited in the summer months, and this is when the great majority of tourists arrive in these islands, the whole analysis has been carried out in six months only: from May to October included. In other words, we assume that there is no thermal stress (and hence, no impact on tourism) in the rest of the year.

Initially, three islands were investigated: Corsica, Sardinia, and Sicily, given the massive amount of potential data. Other estimations were provided for Balearic Islands using the Index of Distance in Destination Image to position each island in a range that goes from Sardinia / Corsica on one side and Sicily on the other side. Without going into the details of the extrapolation method, a summary of results is reported in the following table (see **Table 2.5**).

According to these findings, the average increase in temperature, which is correlated to a growing thermal stress for tourists, brings an economic advantage to tourism destinations. This is only an apparent contradiction with previous findings. This study does not neglect the fact that if islands are too

Table 2.5. Estimation of increase in average price and revenues for Balearic Islands.

Actual share of days in which Humidex > 35 degrees	Future scenario considered	Days in the corresponding scenario in which Humidex > 35 degrees	Increase in the average price	Increase in the tourism overnight stays	Increase in tourism revenues
28.99%	RCP 2.6 near	37.10%	3.0%	0.6%	3.6%
	RCP 2.6 far	36.22%	2.7%	0.5%	3.2%
	RCP 8.5 near	38.30%	3.4%	0.7%	4.1%
	RCP 8.5 far	62.85%	12.5%	2.5%	15.3%

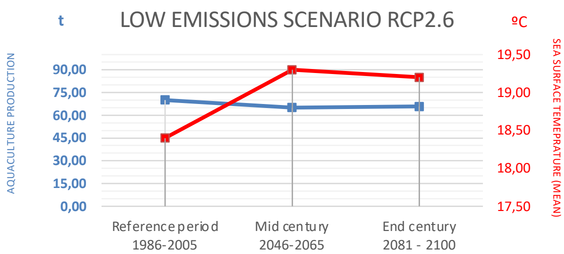
Source: SOCLIMPACT Deliverable Report - D5.3. Data Mining from Big Data Analysis.

hot, tourists will choose to move to other (cooler) destinations, that theoretically exist. Then, the increase in tourism (and tourism revenues) stem from the fact that, when the temperature is too hot, people would prefer to move to coastal areas (where the climatic conditions are more bearable) than staying inland or in cities. Future trends will also facilitate this pressure of tourism demand (think about the spreading of smart working activities where, in principle, the worker can relocate wherever he/she wants).

2.5.2. Aquaculture

The effects of increased sea surface temperatures on aquaculture production were calculated using a lethal temperature threshold, and considering the production share of the region. Four different future scenarios shown by IPCC estimations (RCP2.6 and RCP8.5 near and distant) were analysed, which correspond to four water temperature increases in the region (mean values), with respect to the reference period.

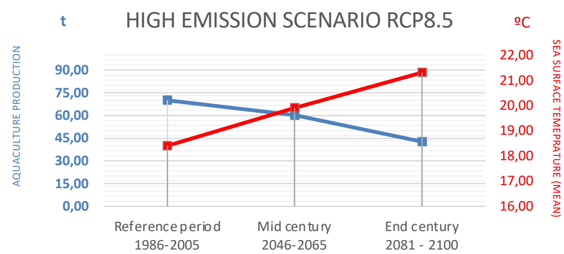
To do this, we assume one main species cultured in this region: mussels, and a model of production function, calculating the monthly biomass production which depends on the monthly water temperature. Results are presented on yearly base (mean values). In order to facilitate the interpretation of the results, we present the value of production of the last year available, for which we calculate the new values under the different climate change scenarios. As expected, the production levels (tons) will decrease for both, low and high emissions scenarios (see **Figure 2.26**).



70.00 *	65 .03 (-7.1%)	65.73 (-6.1%)
18.4	19.3	19.2

*Source: data provided by regional stakeholders to the Soclimpact project

PRODUCTION SHARE	%
MED, MUSSEL	100



70.00 *	60.20 (-14%)	42.70 (-39%)
18.4	19.9	21.3

*Source: data provided by regional stakeholders to the Soclimpact project

Figure 2.26. Estimations of changes in aquaculture production (tons), due to increased sea surface temperature.
Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

2.5.3. Energy

Climate change may impose welfare reductions to the European islands' societies by affecting thermal comfort. Cooling Degree Days (CDD) are a measure of how much (in degrees), and for how long (in days), outdoor air temperature is higher than 21 °C. The CDD is used as a measure of the energy needed to cool buildings. The increase in CDD and the energy demand (GWh/year) for cooling are estimated for the islands, under different scenarios of global climate change.

Under the high emissions scenario, it is expected that the CDD[2] increase to 712 CDD approximately. Under this situation, the increase in cooling energy demand is expected to be 277 % (see **Figure 2.27**).

The Standardized Precipitation Evapotranspiration Index (SPEI) is analysed as a representative indicator for increases in water demand for islands' residents, tourists and agriculture, while it also provides an indication on the available water stored in dams or underground resources. To estimate the increase of energy demand due to the increase in water demand, it was assumed that most of the islands will have to produce desalinated seawater (or groundwater) to meet further increases of demand. Thus, the estimation of the increase in energy demand (GWh/year**)** to produce more drinking water has been done based on the energy consumption required to desalinate seawater. Under the high emissions scenario (RCP8.5), the situation could become critical as the indicator reach the highest levels, which could lead to an increase of 153 % in desalination energy demand (see **Figure 2.28**).

[2] The indicator is computed by multiplying the number of days exceeding the threshold by the difference in temperatures.

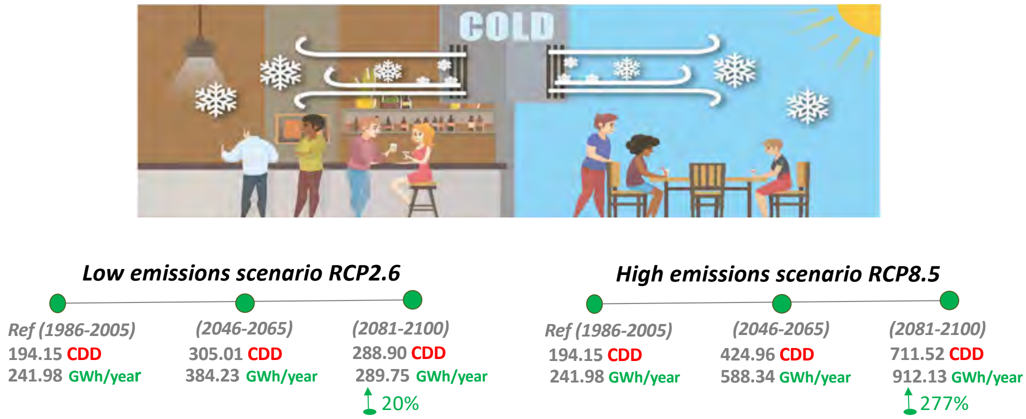


Figure 2.27. Estimations of increased energy demand for cooling in Balearic Islands under different scenarios of climate change until 2100.

Source: SOCLIMPACT Deliverable Report D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

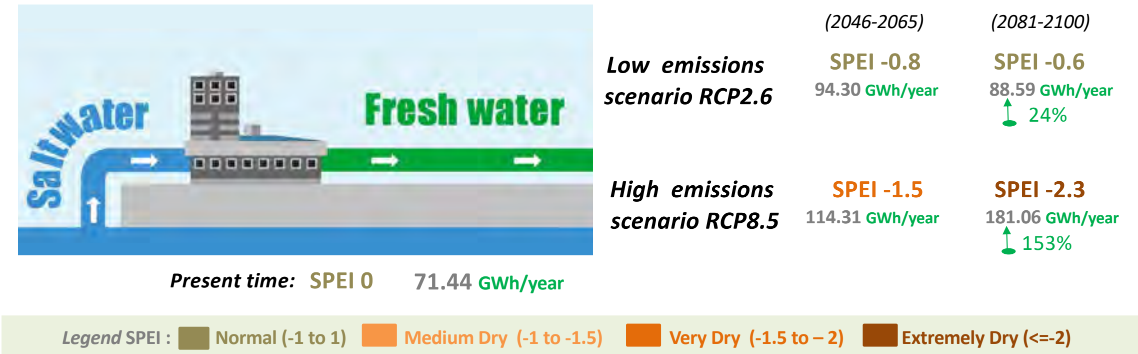


Figure 2.28. Estimations of increased energy demand for desalination in Balearic Islands under different scenarios of climate change until 2100.

Source: SOCLIMPACT Deliverable Report D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

2.5.4. Maritime Transport

For maritime transport, it has been estimated the impact of Sea Level Rise on ports' operability costs of the islands. The costs have been calculated with reference to 1 meter; that is, the investment needed to increase the infrastructures' height by 1 meter. There is not necessarily a strict correspondence between the SLR and the required elevation of port infrastructures, which also depends on the coastal hydrodynamic and the shape of dikes of each port. By experts' recommendation, we have assumed that 1 m increase in port height is required to cope with the SLR under RCP8.5 scenario of emissions. Extrapolation for other RCP scenarios is then conducted based on proportionality.

The starting point was the identification of the principal ports on each island (economic relevance). Second, the analysis of the different port areas (exterior, ramps, oil, etc.), and their uses. Third, the elevation costs were estimated per each area and port separately (considering 1 meter elevation). Thus, the costs of 1 meter elevation presented are the sum of all areas and ports analysed, and including the rest of the ports of the island (if applicable) based on proportionality. According to the estimations, all ports areas of the entire area should be elevated at the same time. In other words, the economic values can be interpreted as the depreciation (amortization) costs of the investment needed to increase all porsts' infrastructures' in the island for 125 years time horizon. No discount rate has been applied.

As expected, the rising of sea levels will affect the sector, as new investments will be needed to keep ports' operability. Under the high emissions scenario, it is expected that these costs could increase up to 5.5 million euros per year until the end of the century (see **Figure 2.29**).

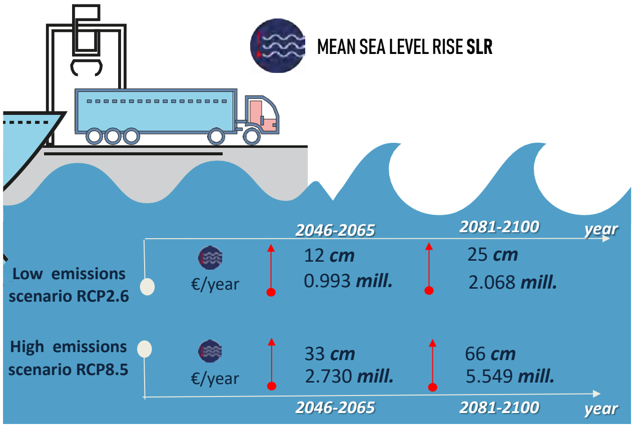


Figure 2.29. Increased costs for maintaining ports' operability in Balearic Islands under different scenarios of SLR caused by climate change until 2100.

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

2.6. Impacts on the Island's Socio-Economic System

The aim of our study is to assess the socioeconomic impacts of biophysical changes for Balearic Islands. For this purpose, we have used the GEM-E3-ISL model, a single-region, multi-sectoral general equilibrium model based on the principles of neo-classical theory, and GINFORS, a macro-econometric model based on the principles of post-Keynesian theory.

Both models include 14 sectors of economic activity, with an emphasis on services and specifically on those composing the tourism industry. The GEM-E3-ISL model also includes endogenous representation of labor and capital markets as well as bilateral trade flows by sector.

Changes in the mean temperature, sea level and precipitation rates are expected to affect energy consumption, tourism flows and infrastructure developments. These impact-chains have been examined and quantified under two emission pathways: RCP2.6, which is compatible with a temperature increase well below 2 °C by the end of the century, and RCP8.5, which is a high-emission scenario. The impact on these three factors was used as input in the economic models, which then assess the effects on GDP, consumption, investments, employment, etc.

In total, 16 scenarios have been quantified for Balearic Islands. The scenarios can be classified in the following categories:

1. Tourism scenarios: these scenarios examine the reduction in tourism revenues due to changes in human comfort as captured by the hum-index, the degradation of marine environment, the increased risk of forest fires and beach reduction. The aggregate tourism scenario (TOUR-SC6) assesses the economic impacts of a simultaneous change of all (the above-mentioned) factors.
2. Energy scenarios: the aggregate energy scenario (ENER-SC3) assessed the impacts on regional economic performance of increased total electricity demand driven by cooling and water desalination demand.
3. Infrastructure scenario: this scenario assesses the impact of port infrastructure damages (INFRA-MAR).
4. Aggregate scenarios: these scenarios examine the total impact of the previous-described changes in the economy.

In the aggregate scenario, we examine the impacts of a simultaneous change in electricity consumption, tourism revenues and infrastructure damages. The scenario specifications for the two climatic variants are presented below (see **Table 2.6**).

The theoretical and structural differences of the two models mean that this study produces a reasonable range of impacts, given the uncertainty embodied in economic analysis and especially in the long-term.

In GEM-E3-ISL, the economy is in equilibrium at each point in time. Prices adjust to ensure that supply equals demand (market clearing), capital is fully used; however, the model allows for equilibrium unemployment as it takes into account labor market rigidities. The impacts are driven mainly by the supply side through changes in production costs which influence relative prices; hence, competitiveness and trigger substitution effects. The GEM-E3-ISL model assesses the impacts on the economy up to 2100.

The macro-econometric type of models, such as GINFORS, do not require that all markets are in equilibrium; idle capital

Table 2.6. Aggregate scenario –inputs.

	Tourism revenues (% change from reference levels)	Electricity consumption (% change from reference levels)	Infrastructure damages (% of GDP)
RCP2.6 (2045-2060)	-8.14	10.80	-0.01
RCP2.6 (2080-2100)	-10.71	4.40	-0.01
RCP8.5 (2045-2060)	-11.36	25.20	-0.01
RCP8.5 (2080-2100)	-34.08	51.20	-0.03

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

and involuntary unemployment are some other features of this type of models where the results are driven mainly by adjustments in the demand side of the economy. The GINFORS assesses the impacts on the economy up to 2050.

With respect to GDP the estimated change compared to the reference case is between -2.2% and -3.4% in the RCP2.6 in 2050 and between -3.3% and -4.5% in the RCP8.5. The cumulative change over the period 2040-2100 is estimated (by GEM-E3-ISL) to be equal to -2.8% in the RCP2.6 and -6.5% in the RCP8.5. In GEM-E3-ISL, changes in tourism revenues are singled out as the main driver of GDP impacts in both climatic variants with the effects being more pronounced in the RCP8.5 in the period after 2070, as the degradation of marine environment strongly influences tourists' decisions and electricity consumption increases considerably compared to the shorter-term (see **Figure 2.30** and **Figure 2.31**).

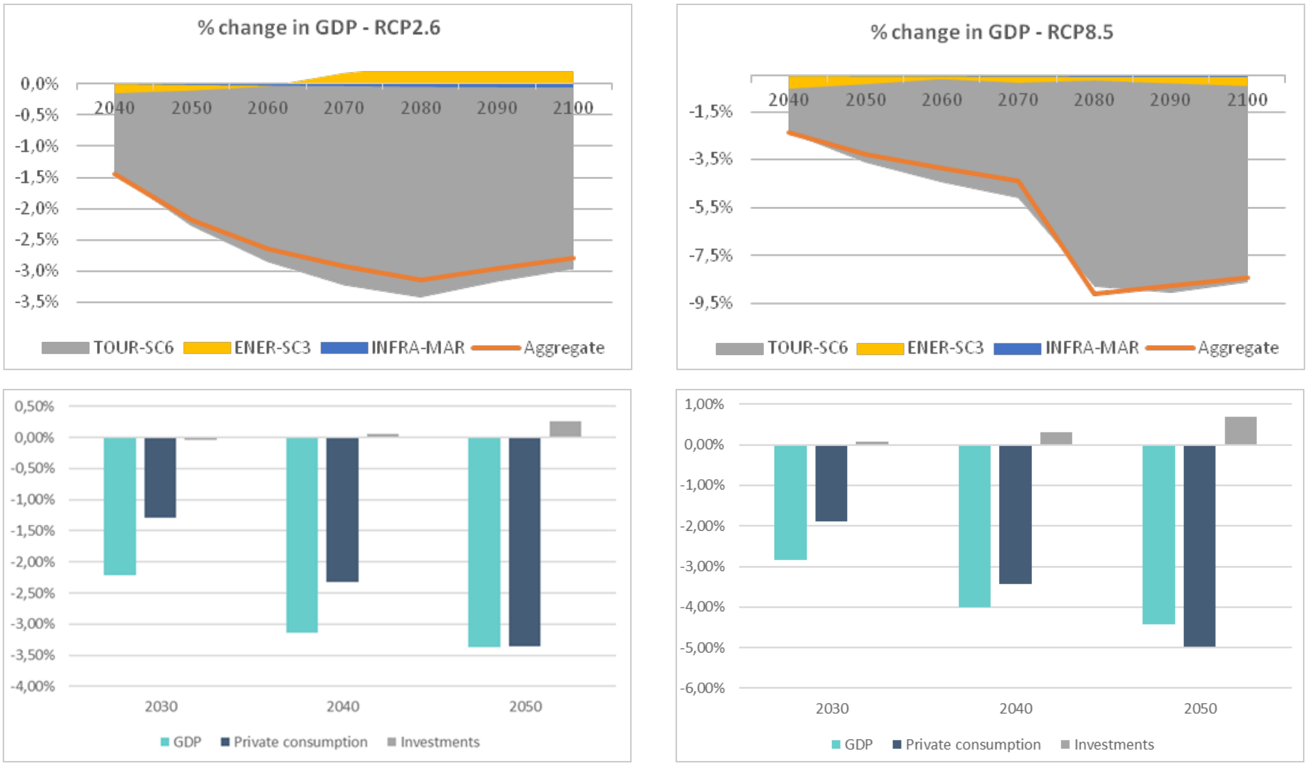


Figure 2.30. Percentage change in GDP. GEM-E3-ISL results (above), GINFORS (below).

Source: own calculation.

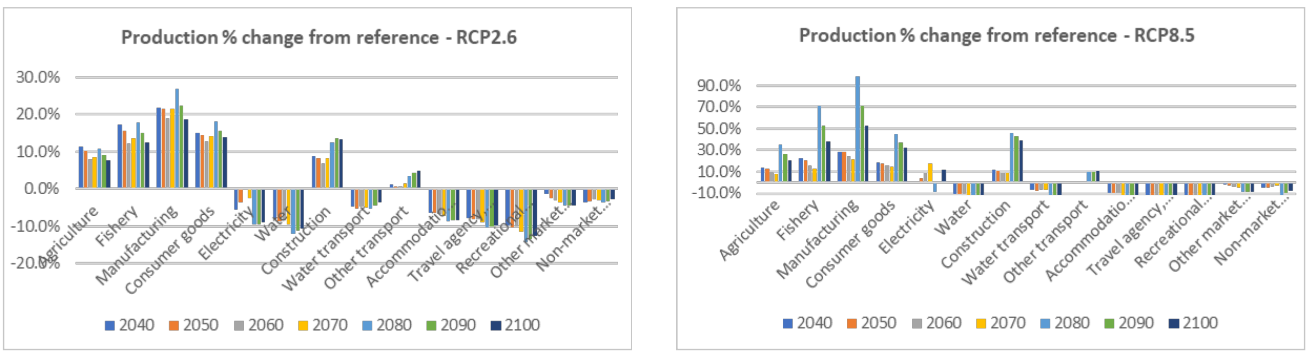


Figure 2.31. Production percentage change from reference: GEM-E3-ISL results.

Source: own calculation. *(Continued on the next page)*

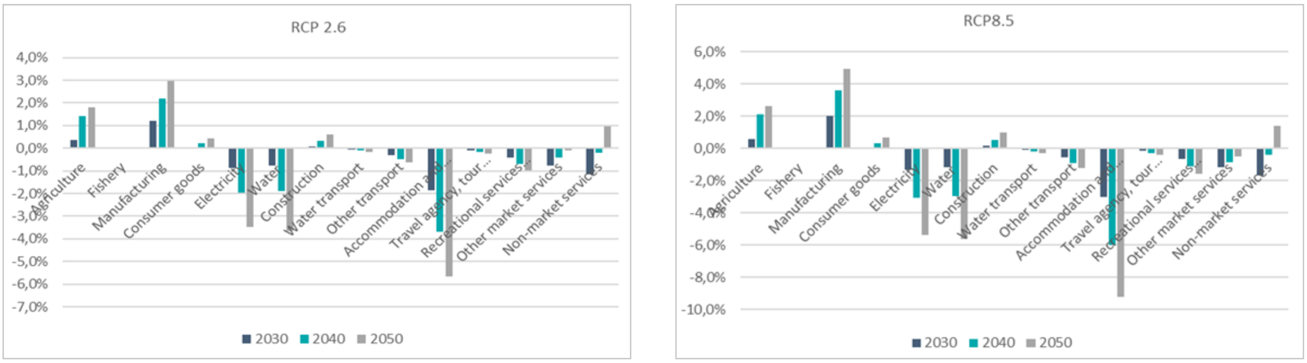


Figure 2.31 (Cont.). Production percentage change from reference: GINFORS results.

Source: own calculation.

With respect to sectoral impacts, both models show a significant decrease in the activity of tourism related sectors and an increase in the activity of the primary and secondary sectors. Construction services also increase driven by the expansion of power generation facilities.

Overall employment falls in the economy and especially in tourism related sectors. In GEM-E3-ISL, the reduction in overall employment is attributed to the decreased activity of tourism related sectors while in the long-run the energy component has also significant influence in employment losses. Increases in the employment in non-tourism related activities are related to labor costs reductions (as wages fall and their competitiveness increases) and a consequent substitution of capital with labor in other sectors. Employment falls on average by 1.6% in the RCP2.6 and by 2.9% in the RCP8.5 (see **Figure 2.32**).

Figure 2.32. Employment percentage change from reference. GEM-E3-ISL results (above), GINFORS (below).

Source: own calculation.

2.7. Towards Climate Resiliency

The region should follow the commitments at European and Spanish level with a limited capacity of action as the responsibilities on energy or coastal infrastructures, for instance, are not all held at regional level. In the case of the Balearic Region, and while the Spanish government is finalizing yet his law on climate change, the Governing Council approved in February 2019, the Climate Change and Transition Law Energy of the Balearic Islands. This law is in line with the global targets of reduction of the EU by 2030 and 2050 and, therefore, obliges the Balearic Islands to be responsible in the reduction of emissions and the penetration of the renewable energies. Besides this, only several analyses have been carried out to date, such as the regional roadmap for adaptation to climate change and the assessment of vulnerability of the Balearic Islands, both in 2016.

Also, some strategies can be designed at regional level, but their effective implementation will depend on the regulations and strategies at national level. Furthermore, apart from the lack of political involvement, actions at local level can face the opposition of some economic sectors (basically linked to tourism activities) which are strong and usually reluctant to changes.

Specific limits and obstacles

There is a lack of reliable statistics and information related to exposure and vulnerability of the island to climate change. These are important components that worsen climate risks and respond to human interventions (more pressure). The island' s adaptation focus should be, first, the development of reliable information systems for the periodic monitoring of these components.

Balearic Islands are recognized by its highly intensive tourist activity, and also by their greatest dependence on foreign energy and the smallest share of renewable energy generation among Spanish regions. Therefore, a profound transformation of the energy and production model is required in order to eliminate dependence on fossil fuels.

2.7.1. Policy Recommendations

A stakeholders consultation process was carried out in the island, aiming to propose, analyse and rank alternative adaptation measures for the island. The profile of the individuals participating in these focal groups involved policy and decision-makers, practitioners, non-governmental and civil society organisations, science experts, private sector, business operators and sector regulators at island level.

The main aim of these meetings was:

1. Identify and present the characterized packages of adaptation and risk management options for the island.
2. Develop detailed integrated adaptation pathways, in three timeframes: Short term (up to 2030), Mid-century (up to 2050) and End-century (up to 2100).
3. Evaluate and rank adaptation options for 3 blue economy sectors in the island (energy, maritime transport and tourism).

To this aim, stakeholders utilized five evaluation criteria to rank the proposed measures:

- Cost efficiency: Ability to efficiently address current or future climate hazards/risks in the most economical way.
- Environmental protection: Ability to protect the environment, now and in the future.
- Mitigation win-wins and trade-offs: Current ability to meet (win-win) or not (trade-off) the island / archipelagos mitigation objectives.
- Technical applicability: Current ability to technically implement the measure in the island.
- Social acceptability: Current social acceptability of the measure in the island.

Four scenarios of intervention were analysed, called Adaptation Policy Trajectories which are different visions of future policy adaptation choices:

- APT A Minimum Intervention - Low investment, low commitment to policy change.
- APT B Economic Capacity Expansion - High investment, low commitment to policy change.
- APT C Efficiency Enhancement - Medium investment, medium commitment to policy change.
- APT D System Restructuring - High investment, high commitment to policy change.

It was assumed that adapting to climate change may range from minimal to high cost, and from requiring a small or incremental change to a significant transformation from the *status quo*. However, not all APT scenarios were considered in all islands, especially when their stakeholders had a clear vision on the types of measures with greatest viability. Therefore, the final set of proposed adaptation measures are framed in the islands' socio-economic and political context, have a sectoral perspective, and respond to the islands' future scenarios of climate change. At the same time, the involvement of regional stakeholders in policy design allows them to engage in the effective implementation of climate actions on their island.

In Appendices from K to N, a brief explanation of each adaptation option can be found, classified by type or class: Vulnerability Reduction, Disaster Risk Reduction, Social-Ecological Resilience, and Local Knowledge. The latest group refer to very specific measures proposed by stakeholders in each island to ratify the needs.

2.7.1.1. Tourism

Financial incentives to retreat from high-risk areas was chosen as an ideal measure for the long term since these are much deeper and structural measures that involve relocating people, which are difficult to implement in a short period of time. Public awareness programmes are selected for all time frames, considering awareness as a crucial aspect for citizens to be aware of the importance of nature and its resources as a driver of change. Whereas, in APT C, activity and product diversification are selected for all time frames, regarding this measure as more urgent, in the belief that awareness is most useful when people see real alternatives.

Water restrictions, consumption cuts and grey-water recycling are highly prefearable measures among stakeholders. The urgency to respond to water scarcity, one of the biggest issues in the archipelago. Water must be managed correctly, as there is a great shortage of water, with many tourists, swimming pools, etc. Action must be taken, regulating it more efficiently in order to achieve a responsible management of water.

Drought and water conservation plans represent the most important measure for the region throughout the scenarios. However, APT C includes managing long term risk and coastal protection on the long-term, clearly showing, once again, the issue of water scarcity.

The Efficiency Enhancement scenario (ATP C) is the only scenario which considers Mainstreaming Disaster Risk Management (DRM) in the short-term, because it is something that needs to be developed immediately, while using water to cope with heat waves has been selected for medium and long-term.

Adaptation of groundwater management is considered urgent for APT D in all time frames, due to the importance of a healthy ecosystem; if we protect ourselves, there is no need for a monitoring system. However, incorporating monitoring, modelling and forecasting systems for APT C is important in medium and longer term, because the most severe impacts of climate change will occur in the upcoming years.

Regulating and maintenance services are considered only in scenario APTC, where the priority for dune restoration and rehabilitation is shown, since beaches are already suffering. Then, for the long-term, river rehabilitation and restoration are selected, because right now they are not so affected, but they will be in the future. However, it should be noted that both are deemed important.

Cultural services are only considered for the APT C - Efficiency Enhancement (medium investment and medium commitment to policy change scenario). In this case, the region considered to dedicate efforts in the short and medium-term to preserve and minimize the impacts on biodiversity and ecosystems, while also preserving the attractiveness of the region (Adaptive management of natural habitats). As opposed to ocean pools, in the long-term.

The specific adaptation options for the tourism sector include solutions of various kinds. For example, where the problem of water scarcity throughout the archipelago can be clearly seen, an effective plan of water demand management and investment in reducing losses along the water distribution system is the most urgent adaptation option selected. The issue of huge energy consumption by the tourism sector has become clear, as distributed electric grids powered by renewables are also selected as an urgent measure, showing the need this sector has to transform its energy into renewable sources. The zero sewage discharge to the sea is also clearly emphasized in both APTs, due to the impact it has in the entire marine ecosystem.

Even if they are selected for the end of the century or not, the other measures are also important for the archipelago, but having to choose among six options for three scenarios shows the priority other measures have. Thermal isolation of buildings is crucial since the Balearic Islands Architects Association recognises around 45% of buildings at the island exhibit a deficient level of thermal isolation; and the potential reduction of energy consumption and emissions would range from 30 to 80% with respect to the current levels. Then, the problem of wildfires is mainly due to the lack of management and prevention. Forest fire prevention emphasises the importance of prevention rather than action to extinguish the fire, which would be a much more effective measure. Residual organic matter composting to reduce methane emissions shows how the issue of waste it is also a major problem on the islands, especially the challenge of properly managing organic waste (see **Table 2.7**).

2.7.1.2. Maritime transport

Only the APT C and D scenarios were analysed for the sector, where the adaptation option Insurance mechanisms for ports was selected in all time frames, basically because there is no way to retract from high-risk areas as there is no space available to expand or locate the ports.

Climate proof ports and port activities are clearly seen as a priority. According to stakeholders, climate change risks have to be analysed to better adapt and prepare for those impacts. All investments must take climate change into account before moving forward with them. Considering expansion/retreat of ports in urban planning does not make sense for this archipelago, since there is no possible location for relocating the ports.

The Efficiency Enhancement scenario (ATP C) is the only scenario which considers reinforcement of inspection, repair and maintenance of infrastructure in all time frames over Early Warning Systems (EWS) and climate change monitoring, since the latter, despite being crucial, is already in place.

Marine life friendly coastal protection structures are considered urgent for APT C in the short-term, due to the importance of protecting marine life. As it is currently a process that is already underway, for the medium and long-term combined protection and wave energy infrastructures are selected, being important to ensure that this infrastructure can be made productive from the investments that are made. In contrast, for APT D it is just the opposite.

Table 2.7. Proposed adaptation options for tourism in Balearic Islands.

	Short-term (up to 2030)	Mid-century (up to 2050)	End-of-century (up to 2100)
APT C – Pathway — **Efficiency Enhancement** medium investment, medium commitment to policy change — This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system	Activity and product diversification		
	Local circular economy		
	Water restrictions, consumption cuts and grey-water recycling		
	Drought and water conservation plans		Coastal protection structures
	Mainstreaming Disaster Risk Management	Using water to cope with heat waves	
	Adaptation of groundwater management	Monitoring, modelling and forecasting systems	
	Dune restoration and rehabilitation		River rehabilitation and restoration
	Adaptive management of natural habitats		Ocean pools
	Distributed electric grids powered by renewables	Zero sewage discharge to the sea	Forest fire prevention
APT D – Pathway — **System Restructuring** high investment, high commitment to policy change — This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems	**Short-term (up to 2030)**	**Mid-century (up to 2050)**	**End-of-century (up to 2100)**
	Economic Policy Instruments (EPIs)		Financial incentives to retreat from high-risk areas
	Public awareness programmes		
	Water restrictions, consumption cuts and grey-water recycling		
	Drought and water conservation plans		
	Pre-disaster early recovery planning		
	Adaptation of groundwater management		
	Distributed electric grids powered by renewables	Zero sewage discharge to the sea	Thermal isolation of buildings

Vulnerability Reduction *Disaster Risk Reduction* *Socio-Ecological Resilience* *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

Regulating and maintenance services are considered only in scenario APTC, where the priority for hybrid and full electric ship propulsion is shown, because to lessen the fuel used by ships is crucial, since vessels pollute the marine environment. Then for the long-term, coastal protection structures are selected, because is when the greatest rise in the sea level will occur, and when the structure can be affected.

Local Knowledge options are mainly focused on coastline and infrastructure protection, reflecting how having safe and operational ports is of paramount importance for the Balearic maritime transport sector. The development of an adaptation plan to adequate infrastructure to climate threats to encourage the adaptation of recreational marinas to the main climate change hazards is mandatory. The former focuses on adapting mooring structures, increase of dikes and the free board in old docks, particularly to the rise in sea level, so as to enable the Balearic Islands to maintain and improve their position in international recreational boating and recreational cruise traffic, also highlighting the importance of freight traffic. And the latter, to stimulate and encourage the adaptation of recreational marinas to the main climate change hazards, in order to guarantee the operation and future expansion of recreational sailing. Nautical activities are of special importance for the Balearic Islands tourism, since tourism accounts for about 45% of the GDP.

Also, transfering knowledge and capacities for the adaptation to climate change to the Spanish peninsula and the Mediterranean region will guarantee their future connectivity with the Balearic Islands and the development of the potential of maritime navigation between the Balearic Islands and the Mediterranean region. Lastly, strengthening and preparing the provisioning system, as well as reinforcing and improving storage facilities in the face of possible climatic events, in particular to heat waves, are crucial areas (see **Table 2.8**).

Table 2.8. Proposed adaptation options for maritime transport in Balearic Islands.

<table>
<tr><td rowspan="10">APT C – Pathway
—
Efficiency Enhancement
medium investment, medium commitment to policy change
—
This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system</td><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td colspan="2">Awareness campaigns for behavioural change</td><td>Social dialogue for training in the port sector</td></tr>
<tr><td colspan="3">Diversification of trade using climate resilient commodities</td></tr>
<tr><td colspan="3">Restrict developmentand settlement in low-lying areas</td></tr>
<tr><td colspan="3">Climate proof ports and port activities</td></tr>
<tr><td colspan="3">Reinforcement of inspection, repair and maintenance of infrastructures</td></tr>
<tr><td>Marine life friendly coastal protection structures</td><td colspan="2">Combined protection and wave energy infrastructures</td></tr>
<tr><td colspan="2">Hybrid and full electric ship propulsion</td><td>Coastal protection structures</td></tr>
<tr><td colspan="3">Integrate ports in urban tissue</td></tr>
<tr><td>Development of an adaptation plan to adequate infrastructure to climate threats</td><td>Strengthen and prepare the provisioning system to heat waves</td><td>Improve monitoring systems</td></tr>
<tr><td rowspan="8">APT D – Pathway
—
System Restructuring
high investment, high commitment to policy change
—
This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems</td><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td colspan="3">Insurance mechanisms for ports</td></tr>
<tr><td>Awareness campaigns for behavioural change</td><td colspan="2">Social dialogue for training in the port sector</td></tr>
<tr><td colspan="3">Restrict development and settlement in low-lying areas</td></tr>
<tr><td colspan="3">Climate proof ports and port activities</td></tr>
<tr><td colspan="3">Backup routes and infrastructures during extreme weather</td></tr>
<tr><td colspan="2">Combined protection and wave energy infrastructures</td><td>Marine life friendly coastal protection structures</td></tr>
<tr><td>Development of an adaptation plan to adequate infrastructure to climate threats</td><td>Adaptation of recreational marinas to the main climate change hazards</td><td>Strengthen and prepare the provisioning system to heat waves</td></tr>
</table>

Vulnerability Reduction · *Disaster Risk Reduction* · *Socio-Ecological Resilience* · *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

2.7.1.3. Energy

Financial support for buildings with low energy needs is considered necessary in the short and medium-term, while financial support for smart control of energy in houses and buildings has been selected for the long-term, showing the need of evolving to smart houses in the end-century.

Under APT D, stakeholders see an urgent need for green jobs and businesses, so these may experience a radical change and become able to support the Balearic islands reliance on adaptation energy issues while serving as a form of economic diversification, reducing the dependency on the tourism sector. Then, public information service on climate action are selected for the medium and long-term. Energy storage is also seen as crucial for energy services reliability and decarbonization objectives, since it will be key to the development and penetration of renewable energy.

For Disaster Risk Reduction, and to manage long term risk, the decisions need to be sensible to the level of investment and reflect the climate change risk identified for the region. APT D considers review building codes of the energy infrastructure a priority in the short and medium term, since many things need to be changed in order to adapt to climate change. Then, upgrade evaporative cooling systems can be selected for the long term, in case the technology already exists by the end of the century.

Energy efficiency in urban water management is urgent for the sector in all time frames, showing again the need to respond to the growing problem of water scarcity in the archipelago. The specific adaptation options for the energy sector include solutions of various kinds. Taking APT D, promotion of domestic and small-scale photovoltaic solar energy and financial support for the energy rehabilitation of buildings are categorized as urgent. It is a priority to encourage the massive development of photovoltaic energy sources (the one with most potential on the islands) on rooftops, instead of creating photovoltaic parks that occupy territory that could be used for other purposes. These incentives would allow citizens to install solar panels, thus socialising electricity production.

Then, the mass development of the public transport network powered by renewable energies it is also of vital importance. Improving the public transport network will reduce the GHG emissions, making it much more effective and useful for citizens, in order to encourage its use. In particular, developing the railway network (tramway networks), taking advantage of the existing infrastructure of the old railway network. GHG emissions cannot be reduced if electric individual transport and car-sharing are not encouraged. This measure is focused on individual mobility, promoting the use of hydrogen-powered vehicles. Additionally, encouraging vehicle sharing is useful in order to avoid the need to acquire a vehicle to move around the islands. The concept of sharing includes cars, motorbikes and bicycles.

Then, to condition housing, the development of training initiatives in installation and thermal insulation of buildings would be necessary. Lastly, with the aim of solving or diminishing surplus problems, the idea of promoting storage systems for renewable energy installations is key since besides being the most mature technology with the maximum potential in the islands, photovoltaic energy is the one that everyone can adopt (see **Table 2.9**).

Table 2.9. Proposed adaptation options for the energy sector in Balearic Islands.

	Short-term (up to 2030)	Mid-century (up to 2050)	End-of-century (up to 2100)
APT D – Pathway — **System Restructuring** high investment, high commitment to policy change — This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems	Financial support for buildings with low energy needs		Financial support for smart control of energy in houses and buildings
	Green jobs and businesses	Public information service on climate action	
	Collection and storage of forest fuel loads	Energy storage systems	Energy storage systems
	Review building codes of the energy infrastructure		Upgrade evaporative cooling systems
	Local recovery energy outage capacity	Energy recovery microgrids	Energy recovery microgrids
	Energy efficiency in urban water management		
	Promotion of domestic and small-scale photovoltaic solar energy	Mass development of the public transport network powered by renewable energy	Promoting storage systems for renewable energy installations

Vulnerability Reduction | *Disaster Risk Reduction* | *Socio-Ecological Resilience* | *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

Chapter 3

Canary Islands (Spain)

SOCLIMPACT

This project has received funding from
the European Union's Horizon 2020 research
and innovation programme under
Grant Agreement No 776661

CONTENTS

The Canary Islands at a Glance

The Canary Islands are a Spanish archipelago (the southernmost autonomous community) located in the Atlantic Ocean. Actually, the islands are geographically located in the African Tectonic Plate (at 100 km. away from Morocco), even though the archipelago is economically and politically European.

The seven main islands are (from largest to smallest in area) Tenerife, Fuerteventura, Gran Canaria, Lanzarote, La Palma, La Gomera, El Hierro[1]; but the archipelago also includes some more smaller islands and islets.

The Canary Islands were formed by volcanic eruptions millions of years ago. They have a total extension of 7493 km^2, a population of 2,153,389 inhabitants and a density of 287.39 inhabitants per km^2. The population of the archipelago is mostly concentrated in the two capital islands: around 43% on the island of Tenerife and 40% on the island of Gran Canaria.

The Blue Economy Sectors

- **Aquaculture**

  In the Canary Islands, there are mainly fish farms (seabass, Senegalese sole and seabream). The most important species in the Canary Islands are seabream and European seabass, which represent more than 95% of the aquaculture production in the islands and 22% of the total production of these species in Spain. In 2017, were obtained in Gran Canaria the first productions of penaeid shrimps, but due to the needed land, their development will not be highlighted in our region.

  The total production of fisheries and aquaculture registered in Canarian first-sale ports reached 7810 tons of fish in 2017, with a total value of 43 million EUR. The former represents 36.09% of the fresh fisheries production in the islands, while 63.91% of the production corresponds to fishing. However, aquaculture products represent most of the total production value (58.10%).

- **Maritime Transport**

  The Canary Islands are not self-sustaining, so they depend on maritime transport. This sector plays a significant role in the archipelago's economy, not only because of the islands' dependence on the outside in terms of goods' imports and their condition of outermost region, which drives costs up, but also because of the strategic location of the islands, which are located in the middle of the transatlantic routes.

  In 2019, the passenger traffic amounted to almost 7 million people, while total freight traffic (including goods loaded, unloaded and transshipped) reached 39,667,153 tons. The Port of Las Palmas de Gran Canaria is among the most important national maritime ports, along with the Port of Algeciras, the Port of Barcelona and the Port of Valencia. It has occupied the 100th-120th position with respect to container traffic worldwide in several occasion.

- **Energy**

  The archipelago has seven main islands, with seven independent electrical isolated electrical systems. Only Fuerteventura and Lanzarote are interconnected trough a submarine cable. The small and weak island grids pose a big challenge towards maximizing penetration of variable and intermittent RES generation, without jeopardizing grid stability, quality and guarantee of power supply.

  At the moment, the Renewable Energy covers in the Canary Islands 13% of electricity demand; however, regarding the primary energy balance, it only covers 2% (Canary Islands are still depend on around 98% of oil derivatives). In the smaller island, El Hierro, the hydroelectric power plant was launched in 2014, with a penetration of 20% in electricity balance (but not of the total primary energy of the island). In 2016, it attained almost 40% (again, only on electricity balance), and almost 50% in 2017 (of annual electricity balance). In the first months of 2018, the plant managed to cover 60% of electricity demand thanks to the improvements made by the technicians of ITC.

- **Tourism**

  The economy of Canary Islands relies on the service sector, which accounts for 84.9% of the gross value added (GVA). Activities related to tourism have an especial importance (Instituto Canario de Estadística – ISTAC, 2019).

  The archipelago's beaches, climate and important natural attractions, especially Maspalomas in Gran Canaria and Teide National Park and Mount Teide (a World Heritage Site) in Tenerife (rising to 3,718 meters, the highest point on Spanish soil and the third tallest volcano in the world measured from its base on the ocean floor), make the Canary Islands a major tourist destination with over 12 million visitors per year, especially Tenerife, Gran Canaria, Fuerteventura and Lanzarote.

3.1. Current Climate and Risks

The climate in the Canary Islands is subtropical and arid. The temperature fluctuations are not big. It is characterized by deficient and irregular rainfall, especially in the lower areas (less than 300mm) due to the predominance of the Azores Anticyclone. In the midland's areas exposed to the trade winds, rainfall can reach 800-1000 mm.

[1] The island of La Graciosa is the eighth island, but it is not included in our analysis.

Rainfall is more intense in late autumn, especially in winter, while summer is the driest season of the year. Tenerife, La Palma and Gran Canaria are the islands where it rains the most. In the area of summits, on the higher islands, the trade winds cease to affect, lowering precipitation compared to average, around 400 mm, which in some cases may be in the form of snow.

The temperatures are mild all year round. The south of all the islands registers the warmest temperatures with an annual average above 20 °C. Lanzarote and Fuerteventura are the aridest islands, so this average is generalized. On the other islands, as we go up in altitude, the average annual temperature drops to 14 °C, for example, on the peaks of Gran Canaria, to 13 °C on El Hierro and La Gomera, 9 °C in the higher areas of La Palma or up to 5 °C in Cañadas del Teide (Tenerife) (see **Figure 3.1**).

CURRENT CLIMATE-RELATED RISKS

- Coastal flood High
- Water scarcity Medium

SIGNIFICANT CLIMATE EVENTS

- Floods (2009, 2010, 2013, 2014 and 2015)
- Tropical storm 'Delta' (2005)

CLIMATE CHARACTERISTICS (28.1°N 15.41°W, 23m asl)

Average temperature and precipitation

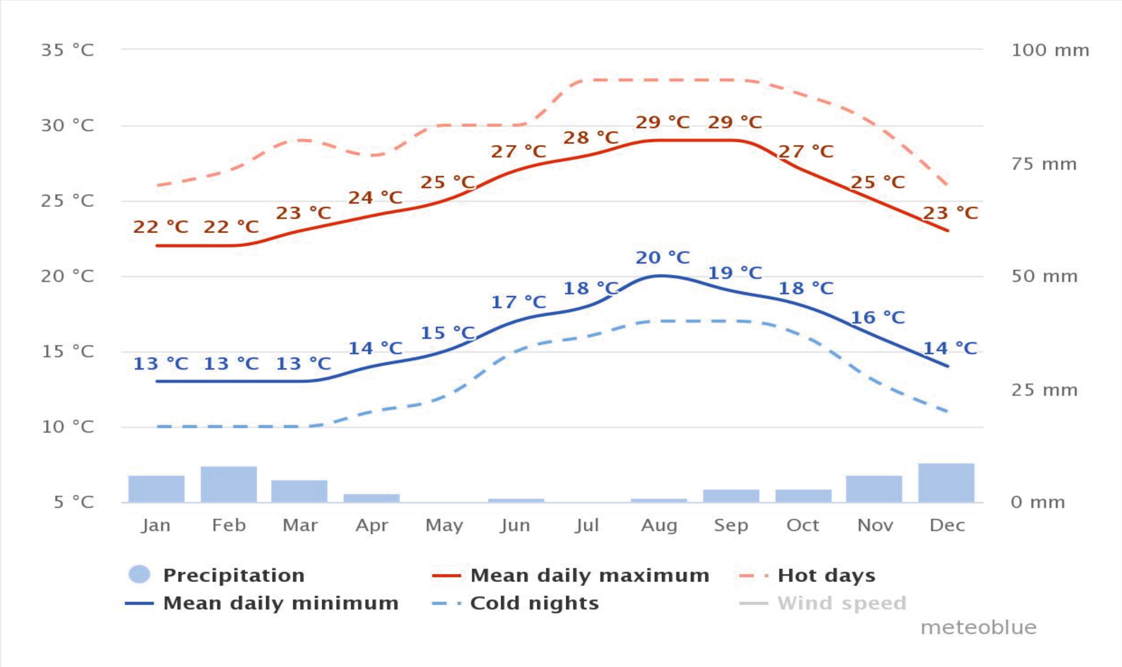
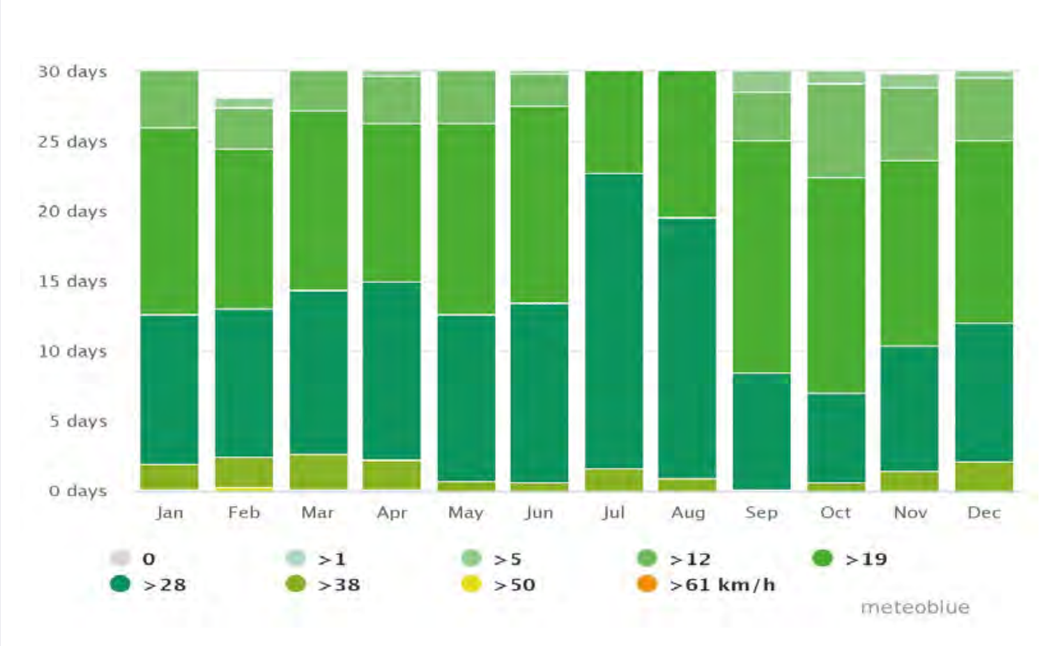


Figure 3.1. Climate factsheet

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System). ***(Continued on the next page)***

Wind speed



Cloudy, sunny and precipitation

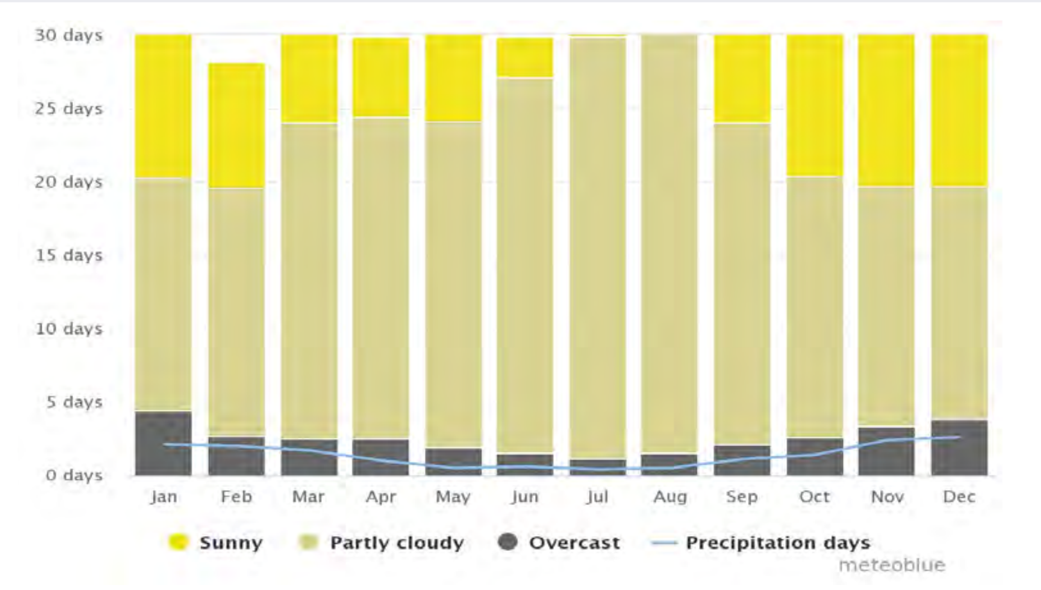


Figure 3.1 (Cont.). Climate factsheet

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System). ***(Continued on the next page)***

Wind rose

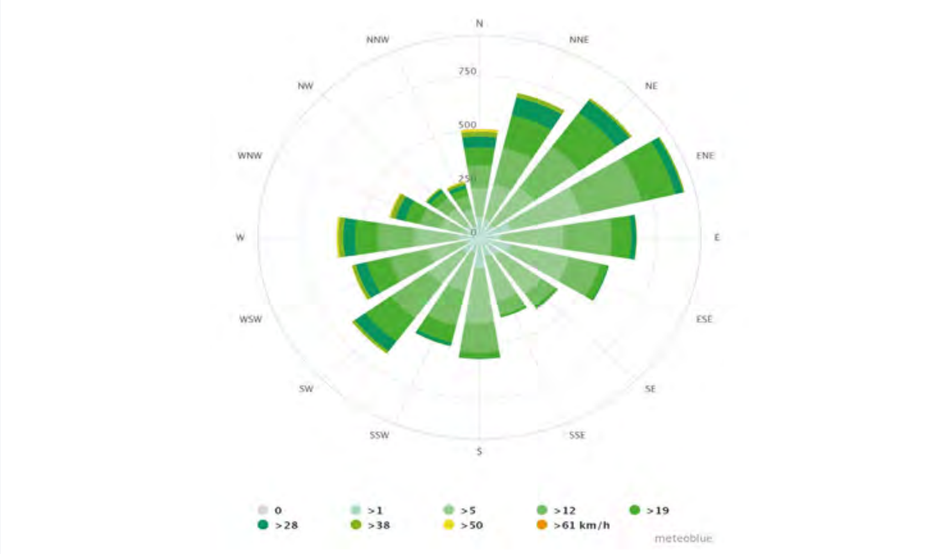


Figure 3.1 (Cont.). Climate factsheet

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System).

3.2. Macroeconomic Projections

According to our reference projections, Canary Islands continue to grow with a 1.6% yearly rate throughout the 2015-2100 period. Main drivers of growth are investments and public consumption with an average yearly growth rate of 1.5% over the whole projection period (**Table 3.1**). While growth rates of private consumption are projected to range around 1%, a long-term reduction of the trade deficit also plays a key role for the sustained economic growth (**Figure 3.2**). This indicates a transition towards a more sustainable economy that reduces its reliance on imported consumption and increases its productive capacity through investment activity.

The high growth contribution of investments in the period up to 2050 is primarily due to a high paced growth towards

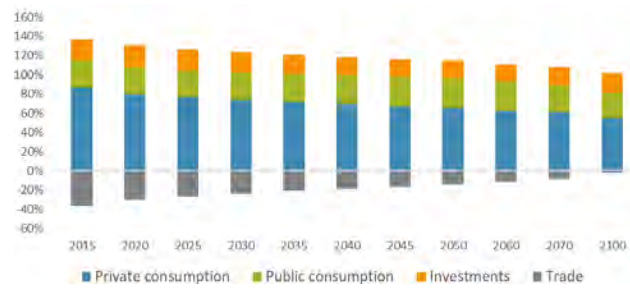


Figure 3.2. Macroeconomic components as a% share of GDP for Canary Islands in 2015-2100.

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

Table 3.1. Canary Islands' GDP and GDP components yearly growth rates in 2020-2100.

	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
GDP	3.0%	1.7%	1.6%	1.5%	1.4%	1.3%	1.2%	1.6%	1.5%	1.4%
Private consumption	1.3%	0.9%	0.9%	0.8%	0.8%	0.8%	0.7%	1.0%	1.3%	1.1%
Public consumption	2.9%	2.3%	2.1%	1.9%	1.7%	1.6%	1.5%	1.3%	1.1%	1.1%
Investments	4.0%	0.6%	0.5%	0.5%	0.5%	0.5%	0.5%	2.0%	1.8%	1.8%
Trade	-0.7%	-0.9%	-1.0%	-1.0%	-1.1%	-1.1%	-1.2%	-1.2%	-1.2%	-3.9%

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

2020 which counterbalances a lack of investments during the economic crisis. Throughout the 2025-2050 period, investments growth rates do not exceed overall GDP growth rates. Private consumption is projected to represent also in 2100 the largest demand component of GDP, followed by public consumption and investments.

3.2.1. The Sectoral Projections

The Canary Islands' economy remains a service-led economy throughout the 2015-2100 period with an increasing contribution of non-market and other market services. The aggregated gross value added share of agriculture, fishery, manufacturing and consumer goods sectors is projected to diminish by roughly 1.5% until 2100. The aggregated share of electricity services, water services and construction services remains relatively stable close to 13% until 2100.

The aggregated gross value added share of total tourism activities is projected to range around 13% throughout the projection period (see **Figure 3.3** and **Table 3.2**).

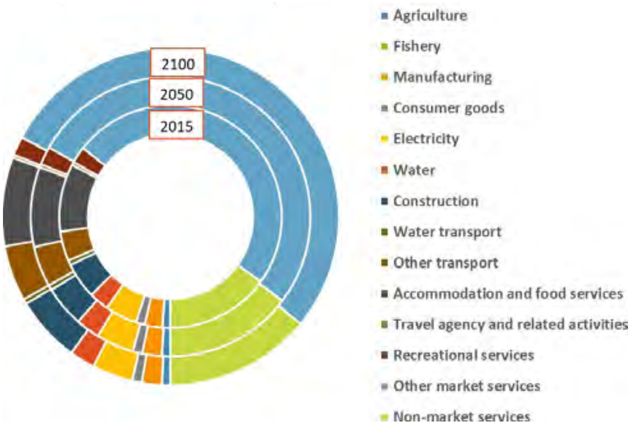


Figure 3.3. Sectoral value added as a% share to total GVA for Canary Islands in 2015, 2050 and 2100.

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

Table 3.2. Sectoral contribution as a% share of total gross value added for Canary Islands in 2015-2100.

GVA % shares	2015	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
Agriculture	1.2%	1.1%	1.1%	1.1%	1.0%	1.0%	1.0%	1.0%	0.9%	0.9%	0.8%
Fishery	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Manufacturing	2.5%	2.4%	2.4%	2.4%	2.3%	2.3%	2.3%	2.2%	2.2%	2.1%	1.9%
Consumer goods	1.3%	1.2%	1.2%	1.2%	1.2%	1.1%	1.1%	1.1%	1.1%	1.0%	0.9%
Electricity	4.7%	4.6%	4.5%	4.5%	4.5%	4.4%	4.4%	4.4%	4.3%	4.2%	3.9%
Water	2.9%	2.9%	2.9%	2.9%	2.8%	2.8%	2.8%	2.8%	2.7%	2.6%	2.5%
Construction	5.2%	5.5%	5.3%	5.2%	5.0%	4.9%	4.8%	4.7%	5.1%	5.4%	6.3%
Water transport	0.7%	0.7%	0.7%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.5%	0.5%
Other transports	4.3%	4.3%	4.4%	4.4%	4.5%	4.6%	4.6%	4.7%	4.8%	4.9%	5.3%
Accommodation & food services	9.8%	9.6%	9.5%	9.5%	9.4%	9.3%	9.3%	9.2%	9.1%	9.0%	8.5%
Travel agency & related activities	0.5%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.3%	0.3%
Recreational services	2.4%	2.3%	2.3%	2.2%	2.2%	2.2%	2.1%	2.1%	2.0%	2.0%	1.8%
Other market services	49.3%	49.9%	50.4%	50.8%	51.2%	51.5%	51.8%	52.0%	52.2%	52.5%	53.2%
Non-market services	15.1%	14.9%	14.9%	14.9%	14.8%	14.8%	14.8%	14.7%	14.6%	14.4%	14.0%

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

3.2.2. Employment

The service-led economic growth brings positive effects to the labour market with unemployment projected to fall from more than 15% in 2015 to less than 7% until 2100. The contribution of each sector to total employment depends on the labor intensity of the sector. The biggest employing sectors are the non-market and market services as well as accommodation and food services. Accommodation and food services together with recreational services, can, therefore, also be identified as some of the most significant employers amongst the Blue Growth sectors under analysis. The lowest contributions to overall employment among Blue Growth sectors can be observed for the fishery sector (see **Table 3.3** and **Figure 3.4**).

Table 3.3. Unemployment rate for Canary Islands in 2020-2100.

	2015	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
Unemployment rate	15.5%	12.1%	10.8%	10.0%	9.5%	9.2%	8.9%	8.7%	8.5%	7.7%	6.5%

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

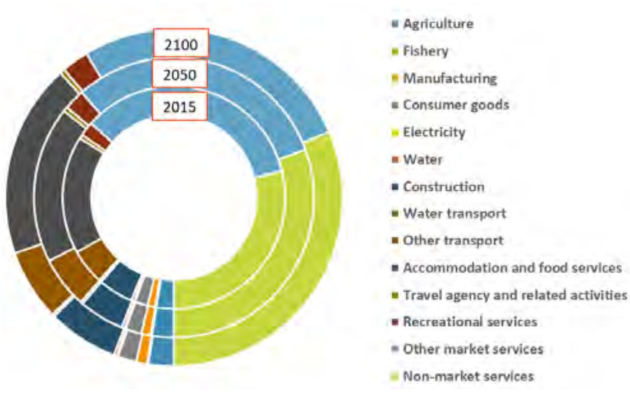


Figure 3.4. Sectoral value added as a% share to total GVA for Canary Islands in 2015, 2050 and 2100.

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

3.3. Climate Change Outlook

Climate hazards indicators represent the entry point to understand the climate change exposure of the blue economy sectors. The indicators have been computed for two scenarios, RCP2.6 (low emission scenario) and RCP8.5 (high emission scenario), and for different horizon times namely: a reference period (1965-2005), mid-century (2046-2065) and end of century (2081-2100). The main source of climate projections for the Canary Islands is MENA-CORDEX, even if other model sources were applied when required. Results are presented in the form of maps, tables or graphs and only when the information shows an interesting outcome.

As to its reliability, it is important to note that Atlantic islands (Azores, Madeira, Canaries and West Indies) lie in very critical areas where global models might be inaccurate in predicting the large scale patterns (regional models are not available), and resolution is so coarse that in fact many islands don't even exist in model orography. This acknowledged, this is the only information we can provide, and at least future tendencies can be inferred. The new CMIP6 simulations might shed more light on these issues, but we can only suggest that results should be updated as they become available.

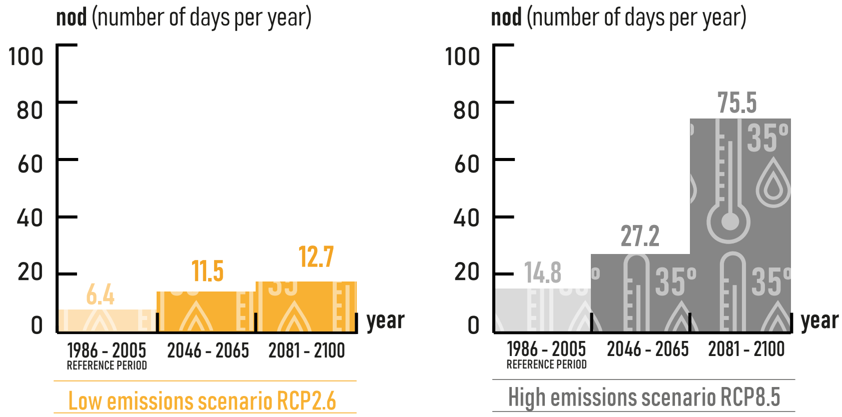
The same partly holds for the wave simulations: local resolution has been significantly increased in the dedicated new simulations of this project, performed by the partner ENEA (up to 0.05°), but the forcing wind field is still derived from the coarse global models.

Stakeholders should be made aware that uncertainty is an inherent characteristic of climate data, and that any future planning must cope with it. Climatologists can only highlight potential threats and constraints, they cannot predict the future and pave the way to solutions. Conveying this piece of information is one of the most critical points of climate change related information.

3.3.1. Tourism

3.3.1.1. Tourist [thermal] discomfort (Humidity Index)

As a representative indicator for the assessment of inhabitants' and tourists' hazard on heat related climate change impacts, the Number of Days with Humidity Index (Humidex) greater than 35 °C was selected. From a predefined classification, a day with Humidex above 35 °C describes conditions from discomfort to imminent danger for humans. For Canary Islands, under RCP8.5 (far future), the number increases (see **Figure 3.5**).



HUMIDITY INDEX-DISCOMFORT LEVEL	
<29°C	comfortable
30–34°C	some discomfort
35–39°C	discomfort; avoid intense exertion
40–45°C	great discomfort; avoid exertion
46–53°C	significant danger; avoid any activity
>54°C	imminent danger; heart stroke.

Figure 3.5. Number of days per year with Humidex > 35° C (Euro-CORDEX).s.

Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed indexes and indicator.

3.3.1.2. Seagrass evolution

Seagrasses are the main habitat for coastal marine ecosystems. They provide different services like sediment retention (and thus, clearer waters), coastal protection (in front of marine storms), shelter for marine organisms, etc. Therefore, the state of seagrasses is a convenient proxy for the state of coastal environment. Our results suggest that no seagrass losses are expected for the three following species located in the coasts of Canary Islands: Cymodocea, Zostera and Halophila (see **Figure 3.6**).

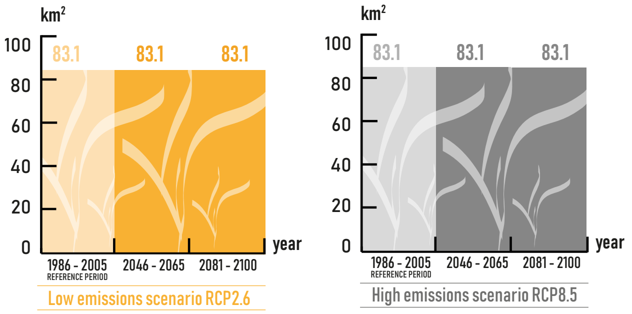


Figure 3.6. Seagrass evolution (covered area in km^2).

Source: SOCLIMPACT Deliverable [Report - D4.4e](). Report on estimated seagrass density.

3.3.1.3. Beach flooding and related losses

One of the consequences of an increase in the mean sea level will be the flooding of coastal areas. This includes sand beaches, which are the main asset for tourism activities in most of the European islands. Therefore, estimating the potential risk of beach loss due to climate change is of paramount importance for the economy of those islands.

The 95th percentile of the flood level averaged was selected as an indicator of interest. The larger projected values are found for the Atlantic islands, where slightly larger Sea Level Rise is combined with the effect of much larger wind waves. The values ranges from 59.92 cm for RCP2.6 to 137.8 cm for RCP8.5 in the far future. Under the RCP2.6, the values are less than half, suggesting that a mitigation scenario could largely minimize the negative impact of climate change on beach flooding (see **Figure 3.7**).

Under mean conditions, we find that, at end of century, the total beach surface loss ranges from ~48% under scenario RCP2.6 to ~80% under scenario RCP8.5 (see **Figure 3.8**).

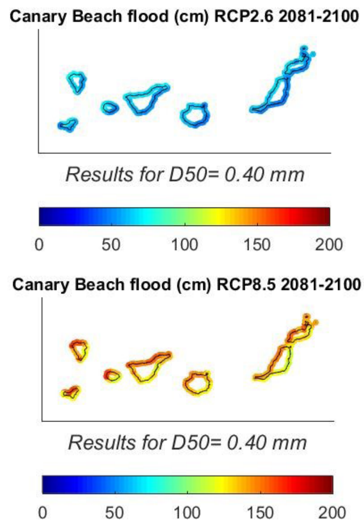


Figure 3.7. Projected extreme flood level (in the vertical) at beach locations with respect to the present (1986-2005) mean sea level values averaged for the island (far future only). Own elaboration based on global and regional simulations.

Source: SOCLIMPACT Deliverable [Report - D4.4d](). Report on the evolution of beaches.

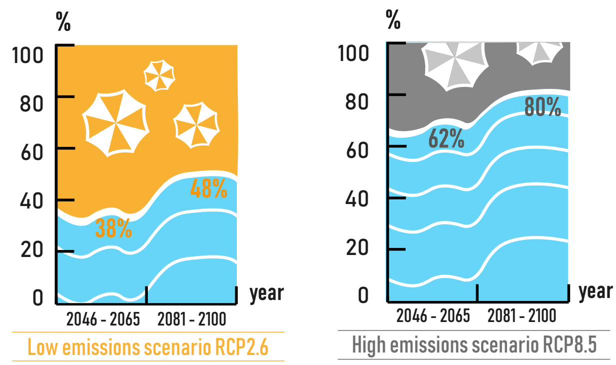


Figure 3.8. Beach reduction% (scaling approximation).

Source: SOCLIMPACT Deliverable [Report - D4.4d](). Report on the evolution of beaches.

3.3.1.4. Fire Weather Index (FWI)

The FWI system provides numerical non-dimensional ratings of relative fire potential for a generalized fuel type (mature pine stands) based solely on weather observations. FWI is part of the Canadian Forest Fire Danger Rating System established in Canada since 1971 (van Wagner, 1987). Furthermore, since

2007, FWI has been adopted at the EU level and used in a harmonized way throughout Europe by the European Forest Fire Information System (EFFIS) of the Copernicus Emergency Management Service (since 2015) (see **Figure 3.9**).

It is selected for exploring the mechanisms of fire danger change for the islands of interest, as it has been proved to adequately perform for several locations, including the Mediterranean basin. The index was calculated for the fire season (defined from May to October) for all models, scenarios and periods. For the Canary Islands, the ensemble means and the uncertainty are presented for all periods and RPCs. Under RCP8.5 there is an increased fire danger: the hazard class changes from medium (reference period) to high.

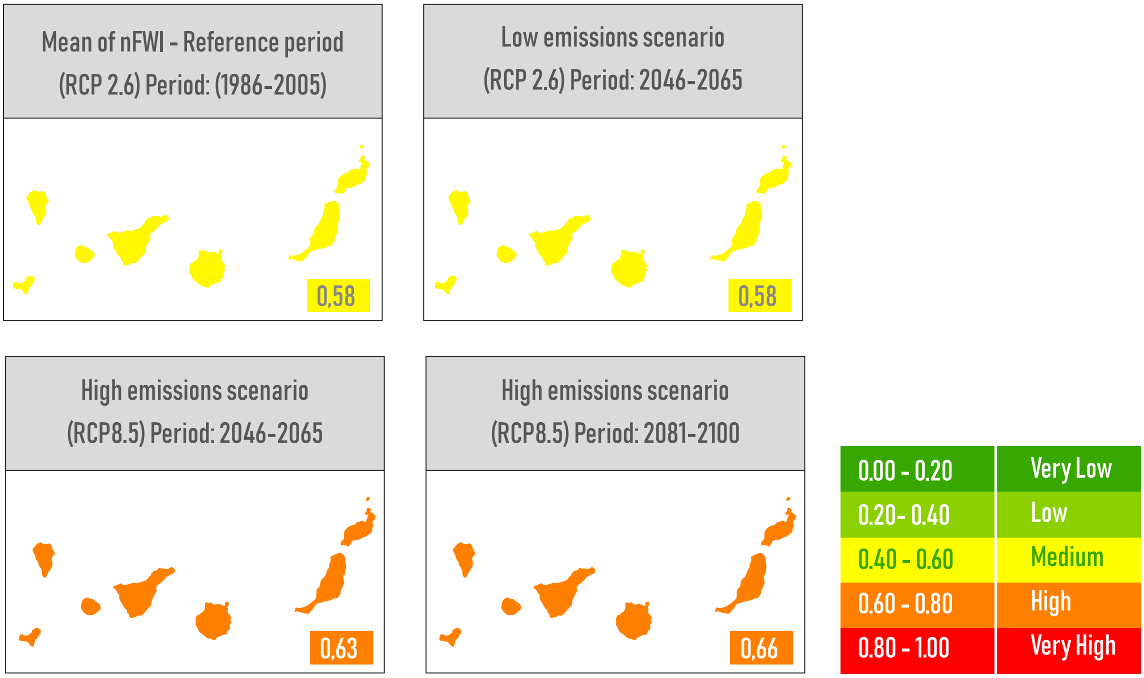


Figure 3.9. Fire Weather Index (EURO-CORDEX) with the color associated to the class of hazard.
Source: SOCLIMPACT Deliverable Report - D4.4c. Report on potential fire behaviour and exposure.

3.3.2. Aquaculture

The predicted impacts of climate change on the oceans and seas of the planet are expected to have direct repercussions on marine based aquaculture systems. The basic effects are listed below (Soto and Brugere, 2008).

- Change in biophysical characteristics of coastal areas:
- Increased invasions from alien species.
- Increased spread of diseases.
- Changes in the physiology of the cultivated species by changing temperature, salinity, oxygen availability and other important physical water parameters.
- Changes in the differences between sea and air temperature, which will alter the seasonality, frequency and severity of storms, cyclones and other extreme events, affecting the stability of the coastal resources and potentially increasing the damages in infrastructure.
- Sea Level Rise, acidification, changes in precipitation and other effects will also add to the changes in coastal ecosystems and environment, thus affecting production and infrastructure (investments).

3.3.2.1. Annual Mean Significant Wave Height (AMSH)

Annual Mean Significant Wave Height was selected as a relevant indicator of the average stress aquaculture infrastructures are subject to. For the Atlantic as a whole, no major changes in wave height mean values are observed, besides a northward shift of the zonal belt where the meridional gradient of the field is strongest. The seasonal means for the reference period are presented hereafter (see **Figure 3.10**).

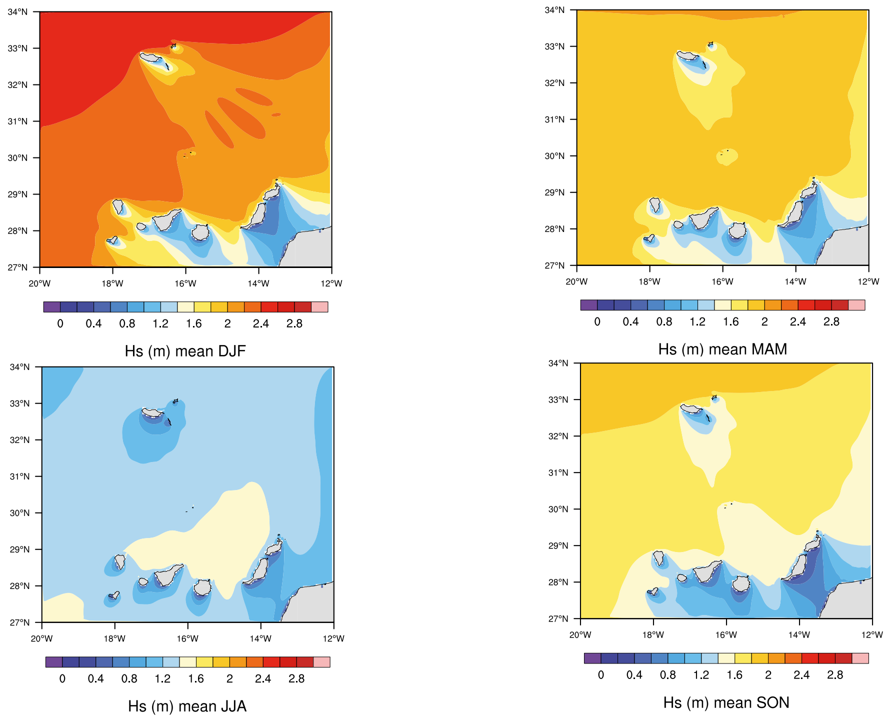


Figure 3.10. Annual Mean Significant Wave Height (seasonal; DJF=Winter, MAM=Spring, JJA=Summer, SON=Autumn).
Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed hazard indexes and indicators with Appendices.

3.3.2.2. Extreme Wave Return Time

Return times for a threshold of 7 m significant wave height (hs) were computed, this significant height having been identified by stakeholders as the critical limit for severe damages to assets at sea. Return times can be related to the payback times of investments and help assess potential economic losses and economic sustainability.

The Atlantic islands under observation deserve special treatment, due to their location in an area that is particularly sensitive to climate change induced changes in the global circulation.

A uniform increase in return times is observed, as the meridional gradient in extreme event frequency experiences a northward shift and is confined within a thinner zonal belt. In the far future and under the RCP8.5 scenario, the Canaries appear to be less exposed to the extreme events potentially harmful to aquaculture infrastructures.

The evident limitation of such conclusions is them being based on a single driving model experiment, which is clearly insufficient to investigate the natural variability of the position and intensity of the observed meridional gradient (see **Figure 3.11**).

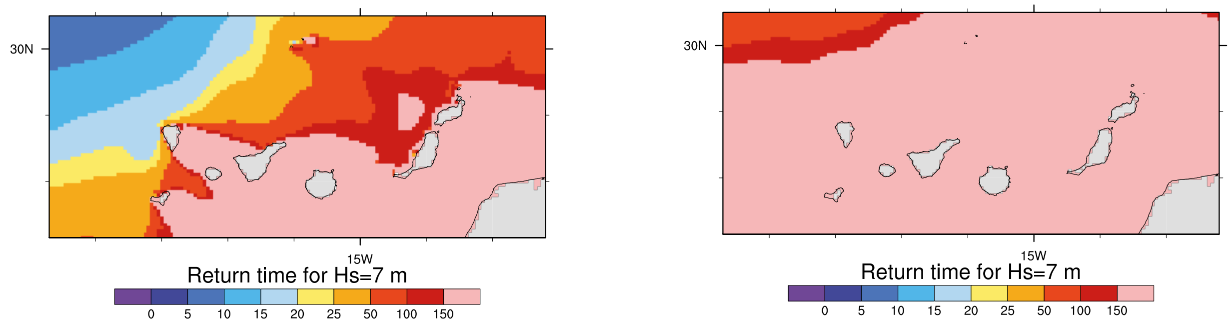


Figure 3.11. Extreme Wave Return Time.
Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed hazard indexes and indicators with Appendices.

3.3.3. Energy

A series of indicators related to renewable energy productivity is presented. The productivity and variability of these renewable energy sources will depend on climate. The possibility of reduced productivity due to climate change poses a risk to the energy generation, if it is based on these renewable energy sources, as well as a possible increase in the frequency and duration of solar and wind energy.

3.3.3.1. Renewable energy productivity indexes

A series of indicators related to renewable energy productivity are presented. The selected indicators are wind and photovoltaic (PV) energy productivity, as well as the frequency and duration of low-productivity periods, termed energy droughts (Raynaud *et al.*, 2018), as a measure of the variability of these sources. The productivity and variability of these renewable energy sources will depend on climate. The possibility of reduced productivity due to climate change poses a risk to the energy generation, if it is based on these renewable energy sources. Also, a possible increase in the frequency and duration of solar and wind energy droughts will require an increase in storage and backup sources.

Among the different renewable energy sources, solar PV and wind energy have been selected, as they are (and very likely will be) the main renewable energy sources, due to their degree of technological development and their comparatively low cost. In order to consider a marine energy source, offshore wind energy is included, in addition to onshore wind energy.

Yearly photovoltaic productivity shows generally small changes over the island (with respect to the yearly productivity of the reference period), with some increases mostly over the mountainous areas of the islands, while coastal areas show mostly decreases. Larger changes are found for RCP8.5, but even for this emissions scenario they remain below 5% over land, pointing towards a stable energy resource.

Time series of PV productivity show the expected seasonal pattern with higher values in central months of the year. In general, a substantial relative interannual variability of PV productivity over the Canary Islands is found, except for summer months. Future negative changes can be appreciated easily in summer in RCP8.5 and RCP2.6, particularly in RCP8.5 at the end of the century. PV productivity tends to decrease also in spring and autumn in RCP8.5. These changes are responsible of the annual mean changes in PV productivity projected over the domain. In other seasons, changes are less clear due to the higher interannual variability (see **Figure 3.12**).

The annual and seasonal variability analysis for wind energy shows that this region has a weak seasonal cycle. The maximum occurs in summer, while the minimum occurs in autumn, although it is very close to winter values. However, models project seasonal changes so that the future seasonal cycle should be even weaker. The increase found in RCP8.5, especially by end of century, is mainly related to the winter, also with a slight increase in autumn. A decrease in summer occurs in both periods (see **Figure 3.13**).

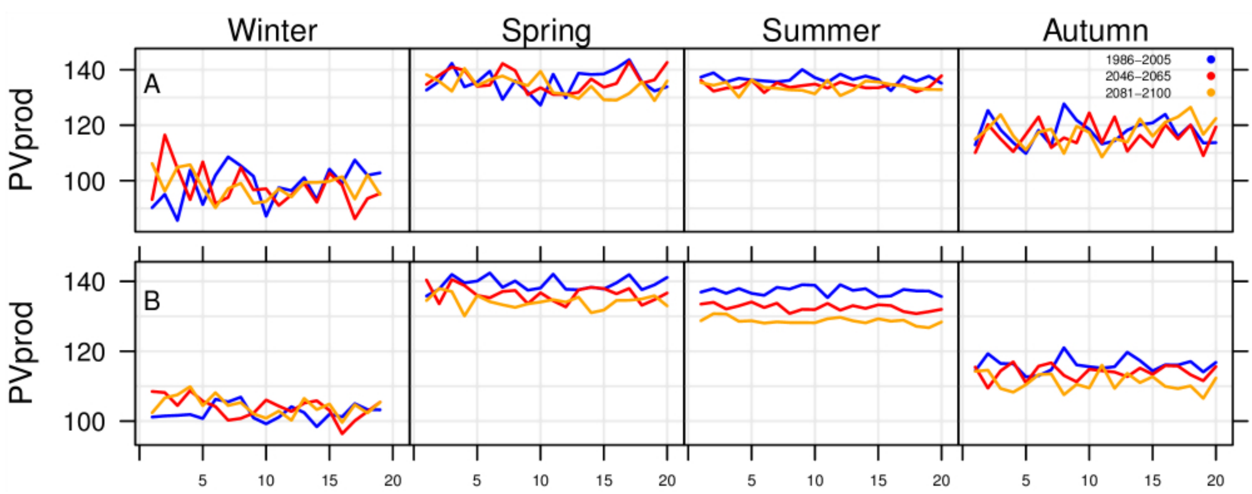
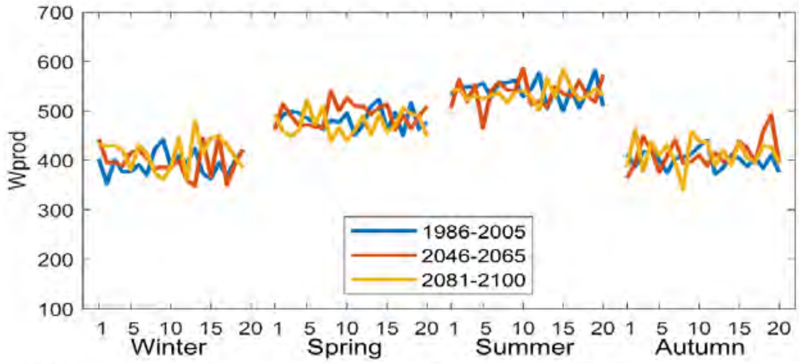


Figure 3.12. Annual and seasonal variability of PV productivity (kWh/kW, in monthly average for each season) for the Canary Islands domain for selected periods for (A) RCP2.6 and (B) RCP8.5. Note that only complete winters (DJF) have been taken into account to construct the time series.

Source: SOCLIMPACT Deliverable Report - D4.4a. Report on solar and wind energy.



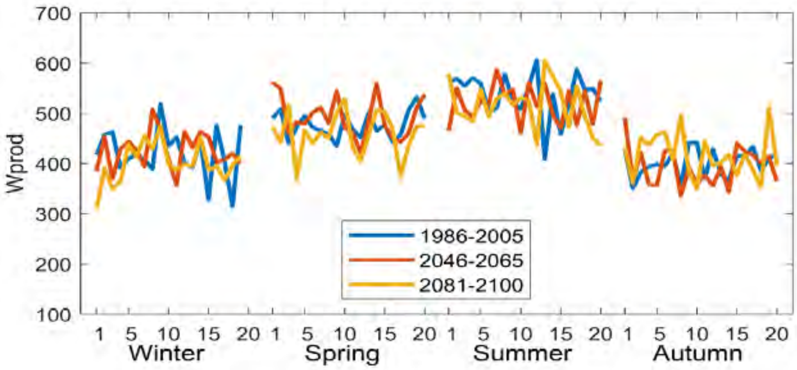


Figure 3.13. Annual and seasonal variability of Wprod (kWh/kW, in monthly average for each season) for the Canary Islands domain for selected periods for RCP2.6 (upper panel) and RCP8.5 (lower panel). Note that only complete winters (DJF) have been taken into account to construct the time series.

Source: SOCLIMPACT Deliverable Report - D4.4a. Report on solar and wind energy.

3.3.3.2. Frequency and duration of low-productivity periods (energy droughts) as a measure of the variability of these sources

Wind energy productivity droughts are generally much more frequent than photovoltaic productivity droughts. Also, the duration of wind energy drought episodes (measured by the maximum consecutive energy drought days) is greater than that of photovoltaic droughts. This highlights the steadiness of photovoltaic production in the analyzed island.

Projected changes in the percentage of days of drought are generally not larger than 5%. For instance, in line with what is found for wind energy productivity, in the Canary Islands we observe a pronounced decrease in the occurrence of wind energy droughts in the RCP8.5 scenario, especially in the second half of the 21st century. Results indicate also that in general, offshore wind energy is less variable than onshore wind energy, as wind energy droughts over the sea are less frequent and last less than over land.

Regarding wind productivity droughts, we observe that these are more frequent in winter and autumn and take the minimum values in summer. This result is consistent with the seasonal cycle of the wind productivity, with maximum values in spring/summer, when wind trades intensify. In both scenarios, interannual variability is larger in the RCP2.6 case, given that this scenario accounts for just one model. In the RCP8.5 scenario, a decrease in the number of wind drought days can be observed in winter and autumn in both time periods. The decreased number of wind drought days found in RCP8.5 scenario can be, therefore, mainly attributed to the wind productivity increase that occurs in winter and autumn (see **Figure 3.14**).

Focusing on PV droughts we note that, in line with what has been found for the wind productivity, droughts are more frequent in winter and autumn (see **Figure 3.15**).

Whilst wind droughts are less prone to occur in spring and summer in both cases, PV droughts are now almost absent in these two seasons. This is consistent with prevailingly anticyclonic conditions in spring and summer and higher atmospheric instability associated with the arrival of Atlantic fronts in winter and autumn. Therefore, annual mean changes in the frequency of PV droughts are largely set by insolation changes in the winter season.

Interannual variations are largest in winter. In the RCP8.5 scenario, PV droughts experience a remarkable drop in fre-

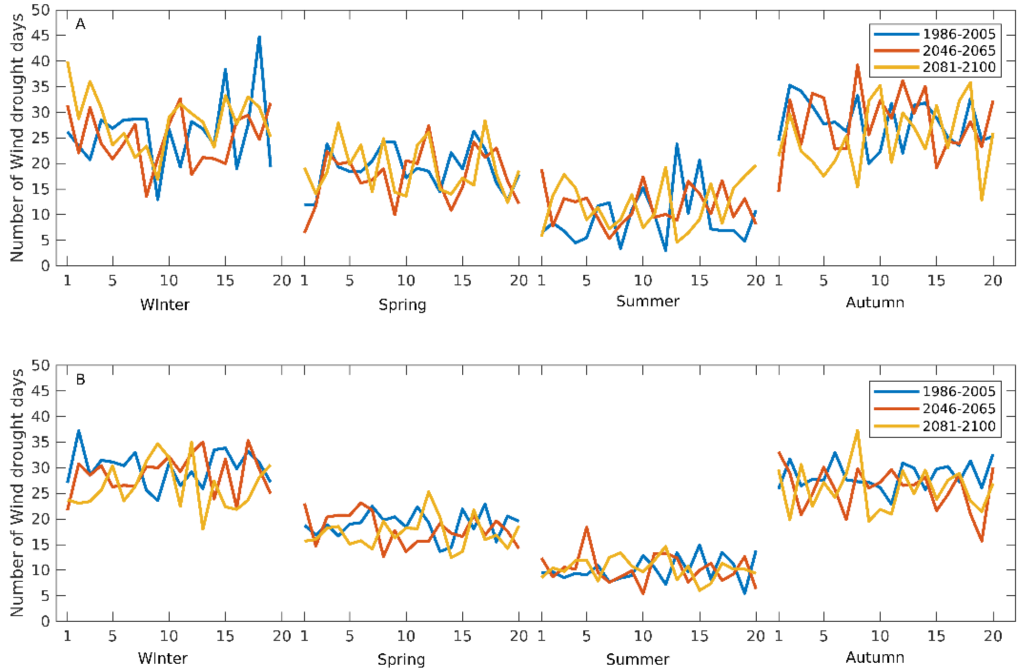


Figure 3.14. Annual and seasonal number of moderate wind drought days for the Canary Islands domain for the selected periods for (A) RCP2.6 and (B) RCP8.5 scenarios. Note that only complete winters (DJF) have been taken into account to construct the time series.

Source: SOCLIMPACT Deliverable [Report - D4.4a](). Report on solar and wind energy.

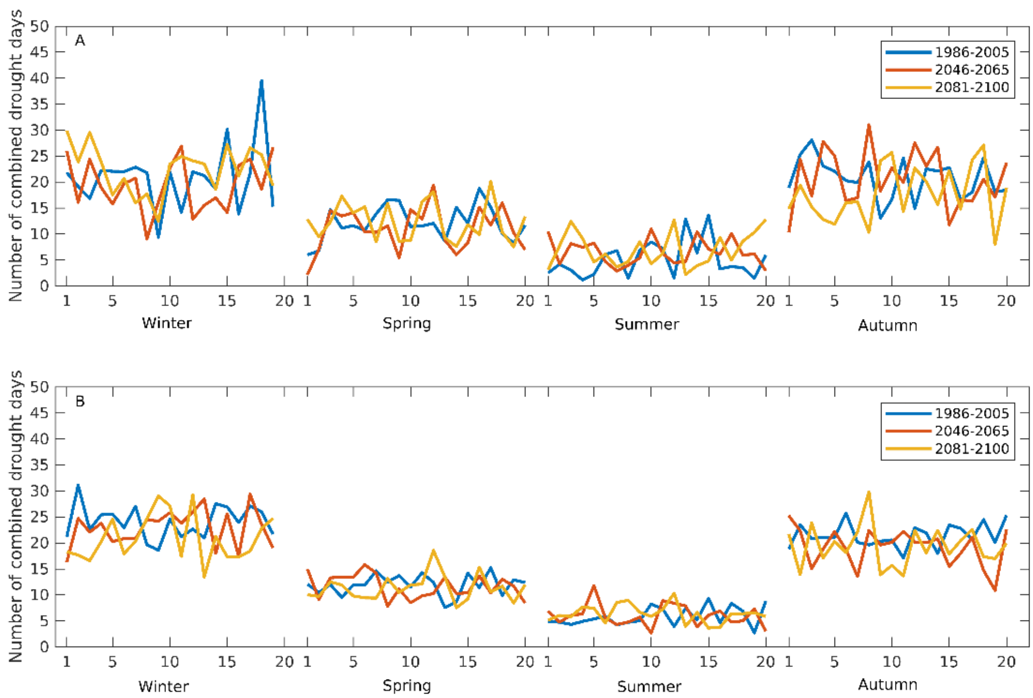


Figure 3.15. Annual and seasonal number of moderate combined PV and wind drought days for the Canary Islands domain for the selected periods for (A) RCP2.6 and (B) RCP8.5 scenarios. Note that only complete winters (DJF) have been taken into account to construct the time series.

Source: SOCLIMPACT Deliverable [Report - D4.4a](). Report on solar and wind energy.

quency in winter, especially at the end of the 21st century. This is again consistent with the subtle increase of the PV productivity observed in this season. In both RCP2.6 and RCP8.5 scenarios, PV productivity experiences a decrease in summer in the two considered time periods. Interestingly, this is not linked to a noticeable increase in the frequency of PV droughts in summer, which suggests that the productivity decrease is mostly evenly distributed among most summer days and is not mainly due to larger daily variability in surface solar radiation.

Regarding the seasonal cycle of combined PV and wind droughts, we note that this is present in all time periods and scenarios, qualitatively similar to that found for wind droughts. However, now the frequency of droughts has a smaller magnitude than in the case of wind droughts, as expected from the combination with a low variability energy source like PV. Wind productivity, which has a greater magnitude and a larger variability in time than PV productivity, seems to control the seasonal cycle to a larger extent. In this case, as for wind droughts, a decrease in the frequency of combined droughts occurs in winter and autumn in both periods of the RCP8.5 scenario.

3.3.3.3. Cooling Degree Days (CDD)

The Cooling Degree Days (CDD) index gives the number of degrees and number of days that the outside air temperature at a specific location is higher than a specified base temperature, providing the severity of the heat in a specific time period taking into consideration outdoor temperature and average room. For RCP2.6 (one model analysis), we found that for near future the increase is almost 60% while at the end of the century this increase will be above 80%. On the other hand, the analysis of the RCP8.5 with 4 models provides a more devastating picture as the number of CDD will be almost 3 times larger than the reference period (see **Figure 3.16**).

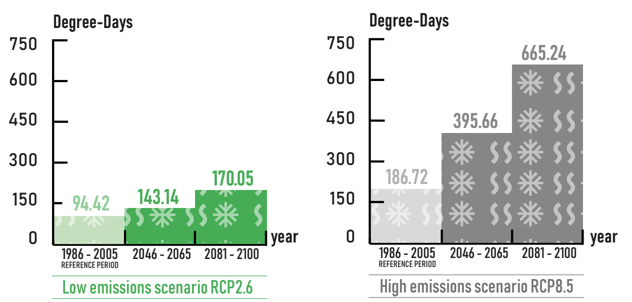


Figure 3.16. Cooling Degree Days. Ensemble mean of MENA-CORDEX simulations.

Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed hazard indexes and indicators with Appendices.

3.3.3.4. Extreme temperature (Percentage of days when T>98th percentile – T98p)

For the assessment of climate hazard on temperature related impacts of climate change on the energy sector, the percentage of days when T > 98th percentile (T98p) has been used. For RCP2.6, the indicator will reach 7% by the end of the century. On the other hand, the RCP8.5 future projections show that, while in mid-century about 7% of the days will be above T98p threshold, at the end of the century, daily temperatures will be above T98p for almost 25% (~90 days per year) of time (see **Figure 3.17**).

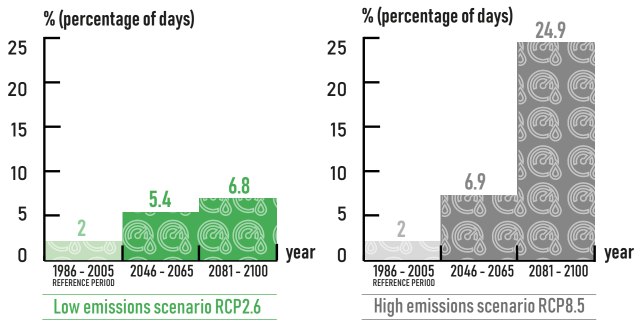


Figure 3.17. Percentage of days when T>98th percentile. Ensemble mean of MENA-CORDEX simulations.

Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed hazard indexes and indicators with Appendices.

3.3.3.5. Available water: Standardized Precipitation Evapotranspiration Index (SPEI)

This index is used as an indication of water availability. The Canary Islands are located in a geographical zone that is expected to be greatly affected by climate change. Although there are much less available simulations for Macaronesia, it is the only case of the investigated islands where a clear transition to drier conditions is evident even under the ambitious pathway.

In particular, Gran Canaria, Fuerteventura and parts of Tenerife are projected to experience moderate to extreme dry conditions under RCP2.6. For all islands, the extreme dry thresholds are also expected to be exceeded by the middle of the current century under RCP8.5 (see **Figure 3.18** and **Figure 3.19**).

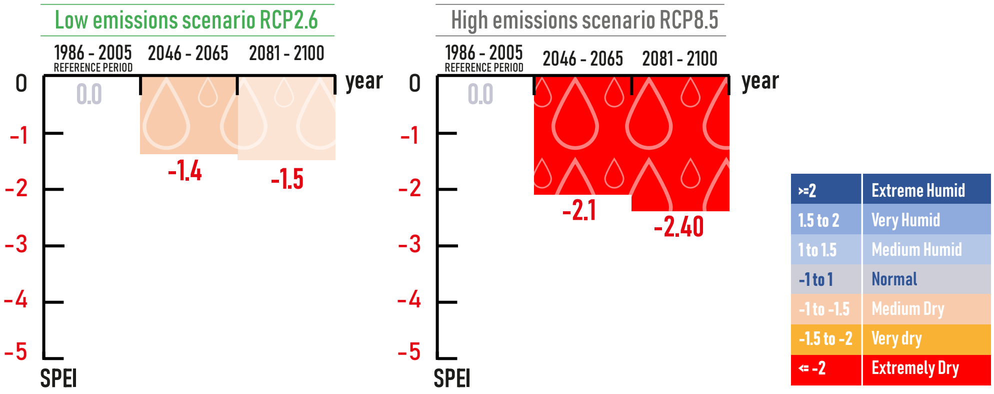


Figure 3.18. Ensemble mean values of the Standardized Precipitation-Evaporation Index (SPEI) averaged.

Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed hazard indexes and indicators with Appendices.

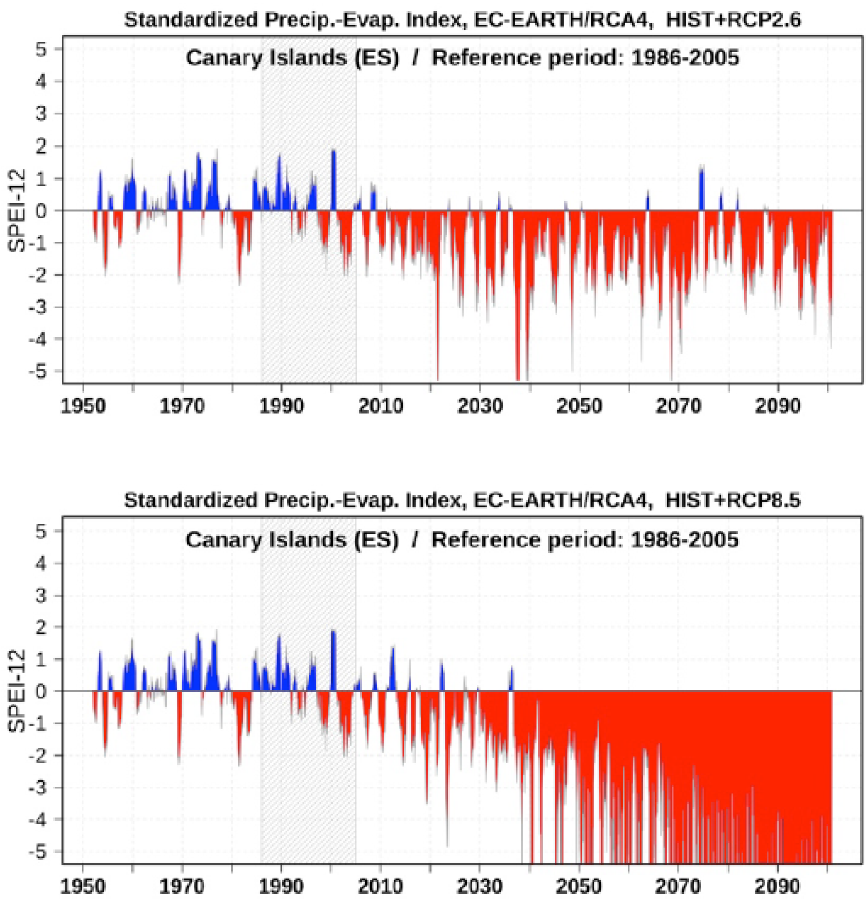


Figure 3.19. Standardized Precipitation Evaporation Index (SPEI) time-series for the RCP2.6 (top) and RCP8.5 (bottom).

Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed hazard indexes and indicators with Appendices.

3.3.4. Maritime Transport

3.3.4.1. Sea Level Rise (SLR)

Sea Level Rise (SLR) is one of the major threats linked to climate change. It would induce permanent flooding of coastal areas with a profound impact on the society, on the economy and on the environment. Moreover, an increase in the mean sea level would result in a larger impact of coastal storms with the consequent increase of risk. The results are presented in terms of averaged Sea Level Rise. For Canary, the SLR ranges from 27 cm (RCP2.6) to 74 cm (RCP8.5) at the end of the century (see **Figure 3.20**).

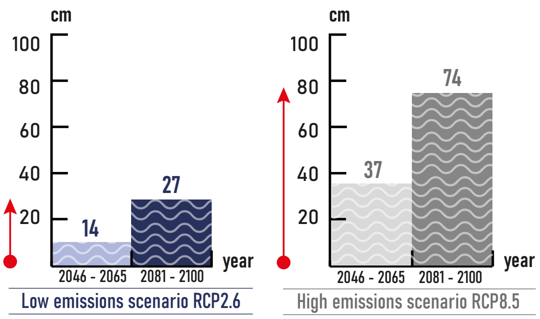


Figure 3.20. Mean Sea Level Rise (in cm) with respect to the reference period (1986-2005). Own elaboration based on global and regional simulations.

Source: SOCLIMPACT Deliverable Report - D4.4b. Report on storm surge levels.

3.3.4.2. Wave extremes (99th percentile of significant wave height averaged)

Marine storms can have a negative impact on maritime transport, coastal-based tourism and aquaculture, among other activities. To illustrate this impact, the 99th percentile of significant wave height averaged has been chosen. A decrease in the extreme wave height is found being larger under scenario RCP8.5, as illustrated in the following map. In relative terms, the averaged changes are lower than 10 % even under this stronger scenario (see **Figure 3.21**).

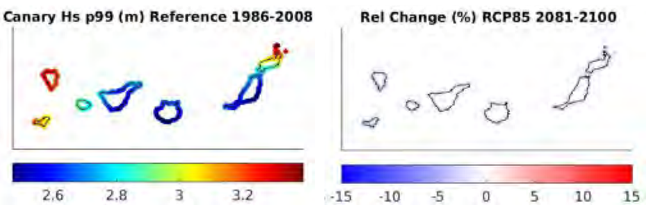


Figure 3.21. The 99th percentile of significant wave height averaged for the reference period and the relative change for the RCP8.5. Own elaboration based on global and regional simulations.

Source: SOCLIMPACT Deliverable Report - D4.4b. Report on storm surge levels.

3.4. Risk Assessment

3.4.1. Tourism

3.4.1.1. Loss of attractiveness due to marine habitats degradation

The Canary Islands hold the best natural conditions to face this risk as all consulted climatic models predict a very low probability of seawater heating to increase over the critical thresholds for the Cymodocea meadows surrounding their seawaters. This and the tourists' perception of the marine attributes sensitivities explain more than 54.7 % of the total risk that the Archipelago exhibits at this regard. This vulnerability is partially compensated by the fact that a great part of its marine biodiversity-based tourist activity depends on ecological processes different than those supported by seagrasses meadows, like cetaceans watching, but still showing high uncertainty about its relationship with this and other climate hazards. Like in the case of the Balearic, the Canary need to develop capacities for tourist diversification bringing other resources to the tourist value generation process. Fortunately, seawater mobility around the islands allow to hide the deficits of an insufficient and inefficiently managed sewage treatment system. The mentioned advantages and disadvantages of the Canary Islands are depicted in the next figures. The further the criteria or sub-criteria is located from the centre of the graph, the more it affects the risk (see **Figure 3.22** and **Figure 3.23**).

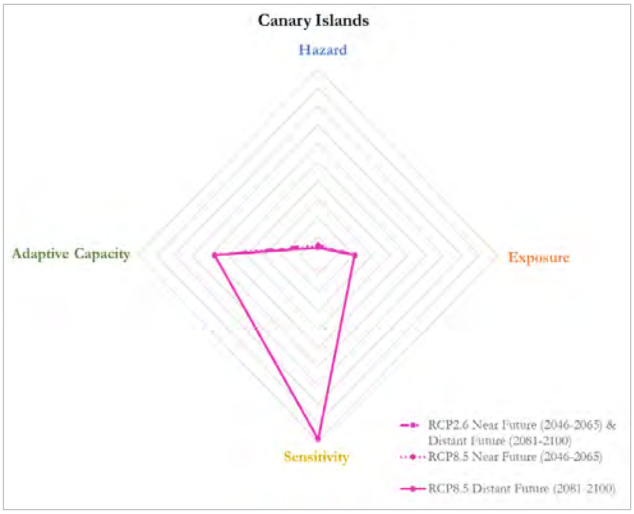


Figure 3.22. Global weights of each criteria and sub-criteria in the final score.

Source: SOCLIMPACT Deliverable Report – D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

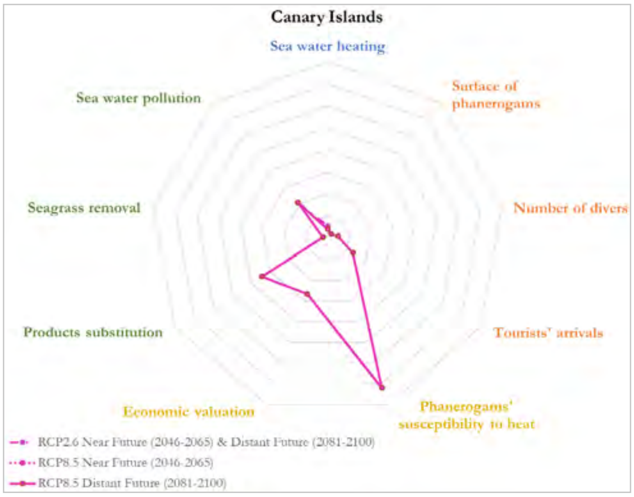


Figure 3.23. Global weights of each criteria and sub-criteria in the final score.

Source: SOCLIMPACT Deliverable Report – D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

The operationalization of the impact chain for the "Loss of attractiveness of a destination due to the loss of services from marine ecosystems" was conducted using the AHP method. The method proved to be appropriate, firstly, for dealing with the hierarchical nature of the impact chain and, secondly, for using expert judgements to assess the comparative risk for the islands over a large number of indicators (sub-criteria). Because the AHP method determines a ranking of the islands, it can provide decision-makers with relative values but not with absolute values.

3.4.1.2. Loss of comfort due to increase of thermal stress

The operationalization of the impact chain for the "Loss of attractiveness of a destination due to a decrease in thermal comfort" was conducted using the AHP method. The method proved to be appropriate, firstly, for dealing with the hierarchical nature of the impact chain and, secondly, for using expert judgements to assess the comparative risk for the islands over a large number of indicators (sub-criteria). Because the AHP method determines a ranking of the islands, it can provide decision-makers with relative values but not with absolute values.

While the Canary Islands are the lowest at risk of loss of competitiveness due to thermal discomfort, they perform badly at "Adaptive Capacity". Moreover, "Exposure" represents the most important criterion for the islands, especially due to the heat-sensitive activities. The mentioned advantages and disadvantages of Canary Islands are depicted in the next figure. The further the criteria or sub-criteria is located from the centre of the graph, the more it affects the risk (see **Figure 3.24** and **Figure 3.25**).

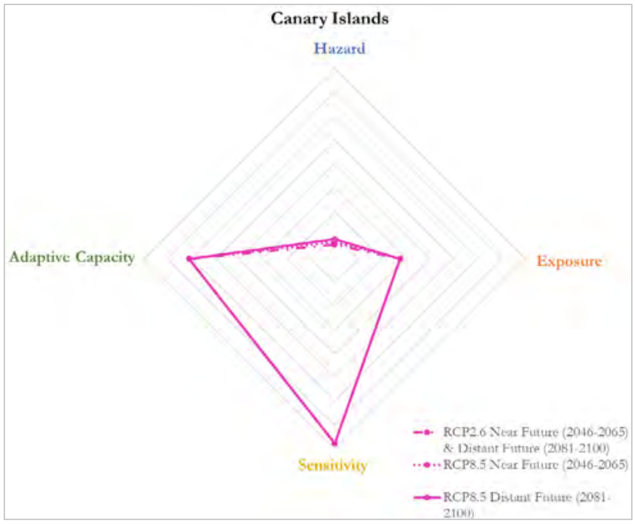


Figure 3.24. Global weights of each criteria and sub-criteria in the final score.

Source: SOCLIMPACT Deliverable Report – D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

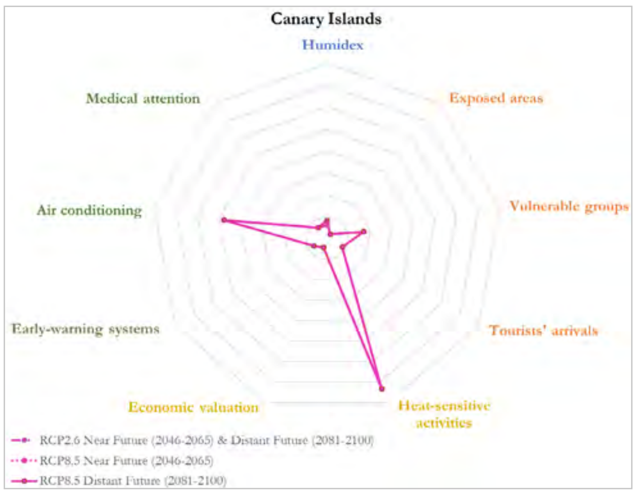


Figure 3.25. Global weights of each criteria and sub-criteria in the final score.

Source: SOCLIMPACT Deliverable Report – D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

3.4.1.3. Loss of attractiveness due to increased danger of forest fires

For the reference period (1986-2005), the overall risk of forest fires is medium for the Canary Islands. This is mainly due to the medium score of fire danger (hazard) and high exposure (high population density and large forest areas). Nevertheless, as vulnerability remains low due to the very low flammability index, in the near future (2046-2065) and distant future (2081-2100), whatever the considered RCP, the risk remains stable with an overall medium risk of forest fires over time. Despite being one of the archipelagos with the highest fire risk in the reference period, in the future the dynamic is maintained, being surpassed by other archipelagos/islands that will have a higher fire risk (see **Figure 3.26** and **Figure 3.27**).

Figure 3.26. Risk score for the reference period.

Source: SOCLIMPACT Deliverable Report - D4.5. Comprehensive approach for policy makers.

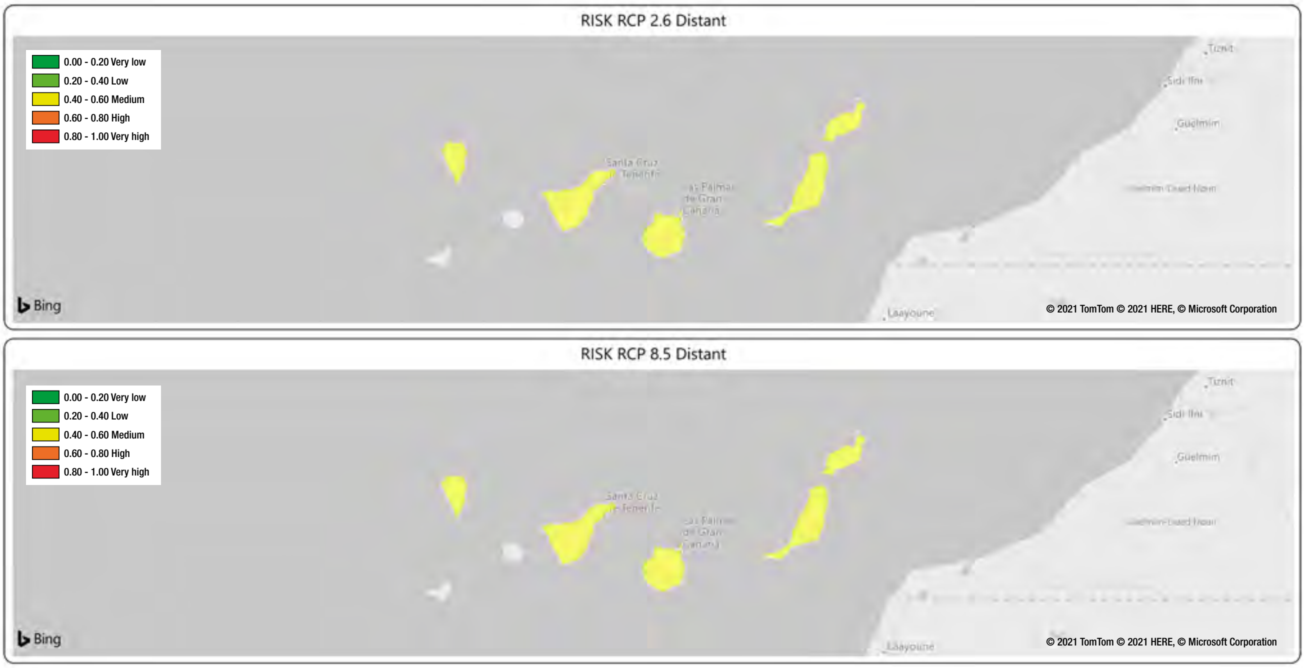


Figure 3.27. Risk score at the end of the distant future (2081-2100) under RCP2.6 (Ambitious Mitigation Policies) and RCP8.5 (Business as usual).

Source: SOCLIMPACT Deliverable Report – D4.5. Comprehensive approach for policy makers.

3.4.2. Energy

The mathematical procedure developed proposes the definition of weights per group of variables (hazard, vulnerability and exposure) that allow identifying the relationship between each of the components and the dependent variable (in this case, energy demand due to desalination or energy demand due to cooling). The detailed weight calculation for the risk components (hazards, exposure and vulnerability) can be found in Appendix I. Hereafter, we only present the final risk scores for increased cooling and desalination energy demand, joint to a general conclusion (see **Table 3.4**).

Table 3.4. Final risk scores for Canary Islands: cooling and desalination energy demand, for the historical and future periods.

	Hist. ref. RCP2.6	RCP2.6 (2046-2065)	RCP2.6 (2081-2100)	Hist. ref. RCP8.5	RCP8.5 (2046-2065)	RCP8.5 (2081-2100)
Cooling	0.30	0.31	0.32	0.33	0.38	0.45
Desalin.	0.29	0.46	0.47	0.29	0.54	0.58

Categorization:

0.00 – 0.20 Very low	0.20 – 0.40 Low	0.40 – 0.60 Medium	0.60 – 0.80 High	0.80 – 1.00 Very high

Source: SOCLIMPACT project Deliverable 4.5. Comprehensive approach for policy makers.

The risk associated to cooling energy demand shows low present values, that almost do not increase in the case of RCP2.6 scenario, while it increases to a medium value at the end of the century for RCP8.5 as a consequence of the temperature increase. The weights of the different components, obtained through an objective correlation method, indicate a higher importance for vulnerability indicators than for hazard and exposure indicators. Specifically, energy intensity and per capita energy demand (vulnerability indicators) show very high correlation with cooling energy demand. The ratio of the yearly number of tourists to population is very high, but it shows a low correlation with cooling energy demand. A possible explanation for this is the very low tourism seasonality in Gran Canaria, as a high number of tourists well distributed over the year seems to have a low impact on cooling energy demand. In contrast, population density shows a high correlation to cooling energy demand, while CDD correlates moderately with this demand.

The low present risk score for desalination energy demand increases clearly even in the mitigation scenario, and doubles toward the end of the century for RCP8.5, as result of the very strong increase of SPEI score. In this case, a higher correlation between the number of tourists and desalination energy demand is found, which increases the weight of the exposure component in such a way that the three risk components have nearly the same weight. The percentage of desalinated water with respect to total water (rising from 20% in 1990 to more than 50% in the last years) shows the highest correlation with desalination energy demand. This indicates that other sources of water are already stressed, and this stress will only increase due to SPEI decreases. But, as the percentage of desalinated water has a higher impact on energy demand than SPEI, once the percentage is near 100%, the increases of desalination energy demand might slow down.

3.4.2.1. Energy demand

- Certain data illustrate the strong impact that demand-side management options can have on energy demand. In the case of Malta, water losses in the distribution network were tackled through a leak management strategy during several years in such a way that the water losses were nearly halved from 2004 to 2009. This factor has been decisive in the evolution of the desalination energy demand, which has decreased 20% from 2004 to 2018 at the same time that GDP has grown 80%; the number of tourists has doubled and drought conditions have worsened.
- A clear demand management option for reducing cooling demand is the improvement of the energy efficiency of buildings. The energy efficiency directive of the EU sets binding targets for all European countries, but the data about the efficiency classes of buildings are rather limited and difficult to access. The scarce data available indicate that there is much room for improvement in this respect. A consequent implementation of energy efficiency measures in buildings could reduce clearly the effect of increasing temperatures on energy demand.
- Digitalisation is key in EU strategies. In this respect, demand side management options for adaptation to generation peaks and troughs should be developed as much as possible through digitalisation, prioritising automatic instead of manual adaptation.

3.4.2.2. Energy supply

- The frame for energy supply in the islands are the binding targets established in the 2030 climate and energy EU framework and the long term horizon of a decarbonized energy system by 2050.
- The future change of wind energy and PV productivity should be rather small in general: around 5% or less with respect to the reference period in many cases, with maximum changes of about 10% for some islands at the end of the century under RCP8.5 scenario (particularly for wind energy productivity over land). A 10% productivity change could have a significant impact on a planned or existing plant if it occurs over the lifetime of the power plant, but in this case, such a change would extend over many decades, which will facilitate adaptation and efficiency measures.
- In general, projections show a decreasing tendency of wind energy productivity over the Mediterranean region, with a more important decrease for the RCP8.5

scenario. The main exception is Crete, which shows a consistent increasing tendency.

- Projected PV productivity changes are generally smaller than wind energy changes. In most cases, PV productivity remains constant or decreases slightly. The main exception is Fehmarn, which shows a clear decreasing tendency in PV productivity under RCP8.5 scenario, reaching a 10% decrease by end of the century.
- There is a specific uncertainty source in the photovoltaic projections. Most regional climate model simulations, including the ones used here, do not include a projected evolution of aerosols in future climate runs. The missed effect of the likely evolution of aerosols would likely increase to some degree the future surface solar radiation and PV productivity over most of the islands (Gutiérrez *et al.*, 2020).
- Renewable energy productivity droughts are a measure of the variability of the resource. Wind droughts are much more frequent (around 50% of the days for most islands) than PV droughts (10% or less of the days). This agrees with results from the study of Raynaud *et al.* (2018), and highlights the stable character of the solar productivity in comparison to wind productivity over time.
- Wind energy droughts are more frequent in the Mediterranean islands than in the Atlantic islands or Fehmarn. The best quality resources in terms of stability are found for Canary Islands, which show the minimum values of both wind energy and PV droughts among all islands. Fehmarn shows by far the worse PV drought score, corresponding a drought frequency of 23% of the days.
- Projected changes in the frequency of droughts are small, with future variations that generally do not attain a magnitude greater than 5% of the days. This indicates that the time-variability characteristics of wind and PV energy are a robust feature, which is relevant for planning the amount of storage or backup needed.
- The combination of PV and wind energy has generally a very positive impact on the frequency of droughts as a result of the complementarity of both sources. This impact also exists but is less clear for islands with substantial summer wind energy resources (Canary Islands, Madeira and Crete).
- As part of the pathway towards very high or 100% RES shares, offshore wind energy should play a very relevant role. Solutions to overcome the obstacle posed by the deep bathymetry surrounding most of the islands are beginning to near commercial deployment, so that floating offshore wind plants are already planned near Gran Canaria and Sicily.
- Offshore PV could be an interesting option for some islands, particularly when land surface limitations are large. There is growing interest in this option, as shown by the test plants being installed and the references made to this technology in the Roadmap for the Offshore Renewable Energy Strategy of the European Commission or in the report of Monitor Deloitte and Endesa (2020) about the accelerated decarbonization of Canary and Balearic Islands.
- The combination of different types of offshore renewable energy sources in the same platform is also attracting interest, as the different sources can exhibit complementarity in time and the combined output can thus be more stable and reliable. The different RES can also share part of the installations, like the connection to land, reducing their cost (Pisacane *et al.*, 2018; MarineEnergy, 2019a). The European Union is trying to promote such combinations, through projects like MUSICA (Multiple Use of Space for Island Clean Autonomy) which will design and test a floating offshore platform integrating wind, PV and wave energy for use on islands (MarineEnergy, 2019b), and plans to develop roadmaps for its deployment in three case study islands, Malta and the Canaries among them (MaREI, 2020).
- New financing possibilities linked to the recently approved EU COVID-19 recovery fund, and over a longer term associated to the European Green Deal, should facilitate the deployment of renewables in the islands, as the energy transition is a key target.
- Interconnections to mainland are very important for supply safety. Excessive dependency on interconnections to mainland should be nevertheless avoided, due to risk of blackouts, as the failure of a single element (one transmission line) can knock out instantaneously a large proportion of the power of an island and even cause an island-wide blackout, as has occurred several times in Malta in the last years.

3.4.3. Maritime Transport

Canary Islands is our only case study archipelago outside the Mediterranean. For the reference period, our analysis indicates low risk values of 0.336. It is, therefore, the second largest risk value after Malta. This result is clearly due to the contribution of exposure indicators. In particular, the total population, number of passengers and value of goods are the highest among all investigated islands. Under an RCP2.6 pathway, risk value is expected to decrease (risk values of 0.250-0.292). This is mainly due to the combination of decreased contribution form adaptive capacity and exposure indicators, since the population of the archipelago was assumed to be reduced following the mainland Spain trends. Under pathway RCP8.5., this reduction of the exposure and adaptive capacity indicators is counterbalanced with a significant increased contribution of meteorological hazards due to climate change. As the Canaries are located in the Atlantic Ocean, the projected mean Sea Level Rise (0.74 cm) is the highest amongst all islands or archipelagos. As a result, the end of the century risk values (0.341) are not expected to exceed the low level class (see **Table 3.5**).

Table 3.5. Summary of present and future risk of isolation due to maritime transport disruption for each island and scenario based on the Impact Chain operationalization.

Risk value per island	Historical reference	RCP2.6 MID	RCP2.6 END	RCP8.5 MID	RCP8.5 END
Cyprus	0.241	0.210	0.218	0.258	0.292
Crete	0.229	0.208	0.201	0.257	0.282
Malta	0.376	0.347	0.335	0.395	0.414
Corsica	0.220	0.194	0.194	0.243	0.273
Canary Islands	0.336	0.292	0.250	0.346	0.341
Balearic Islands	0.326	0.281	0.264	0.331	0.344

Categorization:

0.00 – 0.20 Very low | 0.20 – 0.40 Low | 0.40 – 0.60 Medium | 0.60 – 0.80 High | 0.80 – 1.00 Very high

Source: SOCLIMPACT project Deliverable 4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

3.5. Impacts on the Blue Economy Sectors

3.5.1. Tourism (Non-Market Evaluation)

In order to analyse the reactions of tourists to the impacts of climate change and the preferences for adaptation policies, several hypothetical situations were posed to 300 tourists visiting Canary Islands whereby possible climate change impacts were outlined for the island (i.e., beach erosion, infectious diseases, forest fires, marine biodiversity loss, heat waves, etc.).

Firstly, tourists had to indicate whether they would keep their plans to stay at the island or find an alternate destination if the impact had occurred, which allows predictions of the effects on tourism arrivals to be made for each island. Secondly, tourists were asked to choose between various policy measures funded through an additional payment per day of stay – the tourists' choices being an expression of their preferences for attributes/policies. To estimate the results, the conditional logit model was run by using the Stata software.

In general, data confirms that tourists are highly averse to risks of infectious diseases becoming more widespread (82.30 % of tourists would change destination). Moreover, they are not willing to visit islands where marine wildlife has disappeared to a large extent (71.30 %) or where wildfires occur more often (69 %). On the other hand, policies related to marine habitat restoration (12.75 €/day), water supply reinforcement (11.5 €/day), and cultural heritage protection (8.1 €/day) are the most valued, on average, by tourists visiting these islands (see **Figure 3.28**).

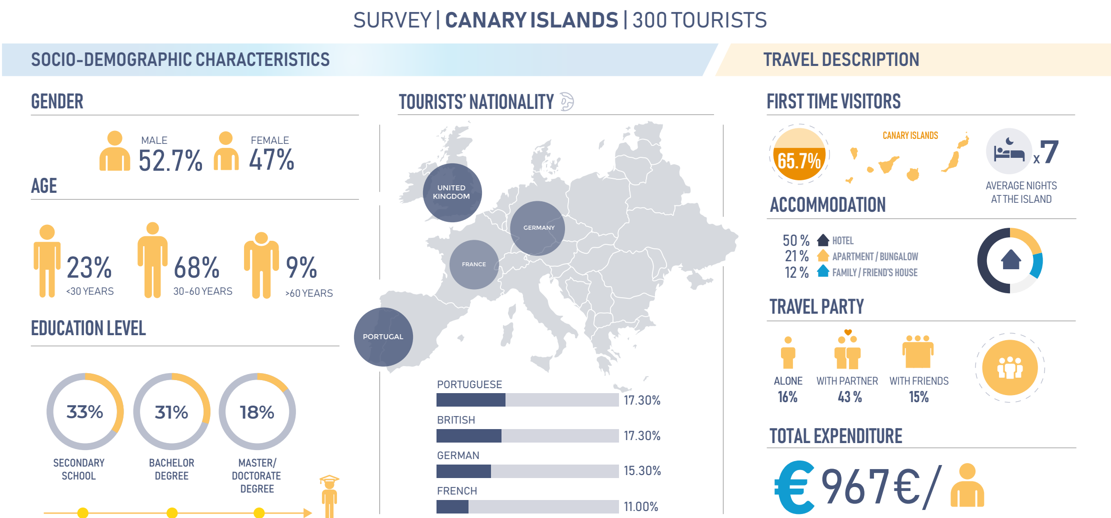


Figure 3.28. Socio-economic characteristics and travel description: tourists visiting Canary Islands.

Source: SOCLIMPACT Deliverable Report - D5.5. Report on market and non-market costs of Climate Change and benefits of climate actions for Europe.

Although climate change impacts are outside the control of tourism practitioners and policy-makers, they can nevertheless utilise this knowledge to improve the predictability of the effect that certain adaptation policies and risk management strategies would have, and develop their plans accordingly (see **Figure 3.29**).

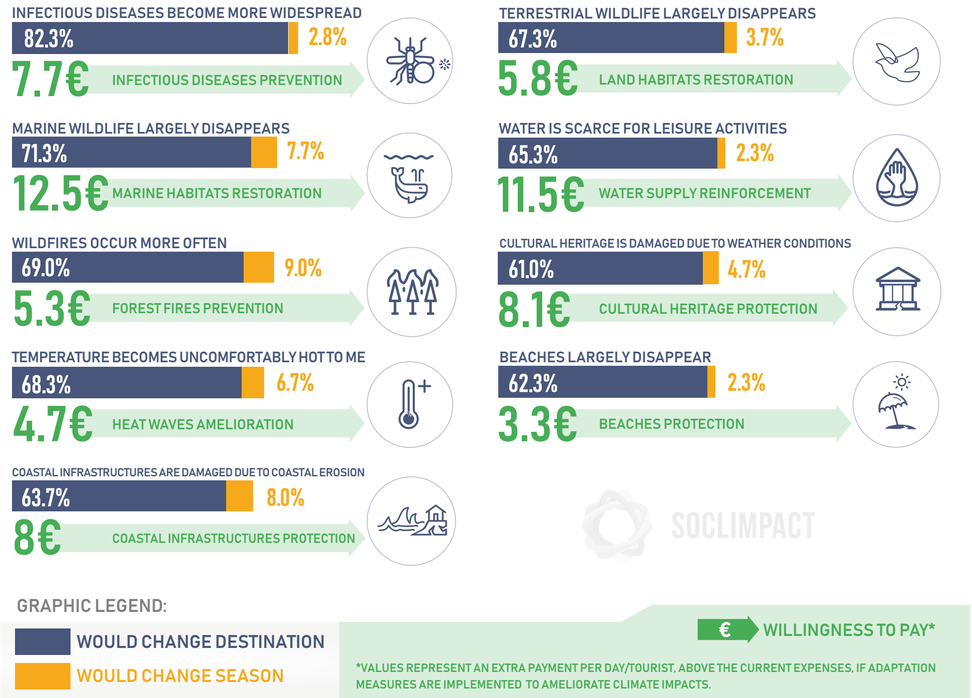


Figure 3.29. Tourists' response to climate change impacts and related policies: tourists visiting Canary Islands

Source: SOCLIMPACT Deliverable Report - D5.5. Report on market and non-market costs of Climate Change and benefits of climate actions for Europe.

The impact of increased temperatures and heat waves on hotels' prices and revenues

In order to assess how the variation in temperature impacts on the tourism sector through changes in tourism demand our research question was: "How do increasing temperatures (and heat waves) impact prices and, more in general, expenditure of tourists?" Arguably, when temperatures grow, tourists adjust their behaviour: they might switch destination, or they might stay longer or shorter depending on their attitudes and preferences. In turn, all these changes modify the market equilibrium, pushing tourism companies to adjust their prices to re-establish the equilibrium between demand and supply. The change in demand and the change in price determine the change in tourism expenditure which is, from the destination's perspective, tourism revenue.

We monitored current weather conditions posted on several weather forecast providers and daily prices posted on Booking.com by hotels. We then estimated the link between daily temperature and daily price, controlling for all the other factors affecting prices. We finally applied these estimates to the increase in the number of days with excessive temperature projected for the future in two scenarios (RCP2.6 and RCP8.5) and in two time horizons (near future, about 2050; distant future, about 2100).

Among the different indicators linked to thermal stress, we focus on two: the number of days in which the temperature is above the 98th percentile and the number of days in which the perceived temperature is above 35 °C. Although the impact for both indices was computed, in this document we only report the second one (named Humidex) because it is the most intuitive and because human thermal stress is more related to the absolute value of the temperature than its deviation from some pre-determined distribution. We assumed that thermal stress appears when the perceived temperature grows above 35 °C. As thermal stress is delimited in the summer months, and this is when the great majority of tourists arrive in these islands, the whole analysis has been carried out in six months only: from May to October included. In other words, we assume that there is no thermal stress (and hence, no impact on tourism) in the rest of the year.

Initially, three islands were investigated: Corsica, Sardinia, and Sicily, given the massive amount of potential data.

Other estimations were provided for Canary Islands using the Index of Distance in Destination Image to position each island in a range that goes from Sardinia / Corsica on one side, and Sicily on the other side. Without entering the details of the extrapolation method, a summary of results is reported below (see **Table 3.6**).

According to these findings, the average increase in temperature, which is correlated to a growing thermal stress for tourists, brings an economic advantage to tourism destinations. This is only an apparent contradiction with previous findings. This study does not neglect the fact that if islands are too hot, tourists will choose to move to other (cooler) destinations, that theoretically exist. Then, the increase in tourism (and tourism revenues) stem from the fact that, when the temperature is too hot, people would prefer to move to coastal areas (where the climatic conditions are more bearable) than staying inland or in cities. Future trends will also facilitate this pressure of tourism demand (think about the spreading of smart working activities where, in principle, the worker can relocate wherever he/she wants).

Table 3.6. Estimation of increase in average price and revenues for Canary Islands.

Actual share of days in which Humidex > 35 degrees	Future scenario considered	Days in the corresponding scenario in which Humidex > 35 degrees	Increase in the average price	Increase in the tourism overnight stays	Increase in tourism revenues
3.51%	RCP 2.6 near	6.30%	1.1%	0.2%	1.4%
	RCP 2.6 far	6.96%	1.4%	0.3%	1.7%
	RCP 8.5 near	14.90%	4.4%	0.9%	5.3%
	RCP 85 far	41.37%	15.2%	3.0%	18.6%

Source: SOCLIMPACT Deliverable Report - D5.3. Data Mining from Big Data Analysis.

3.5.2. Aquaculture

The effects of increased sea surface temperatures on aquaculture production were calculated using a lethal temperature threshold by specie and considering the production share of the region. Four different future scenarios shown by IPCC estimations (RCP2.6 and RCP8.5 near and distant) were analysed, which correspond to four water temperature increases.

To do this, we assume two main species cultured in this region: Seabream and Seabass, and a model of production function, calculating the monthly biomass production which depends on the monthly water temperature. Results are presented on yearly base (mean values). In order to facilitate the interpretation of the results, we present the value of production of the last year available, for which we calculate the new values under the different climate change scenarios.

In both scenarios, the production function will not be negatively affected by the increased sea temperature, as the projected values are under the lethal thershold of the fish species (see **Figure 3.30**).

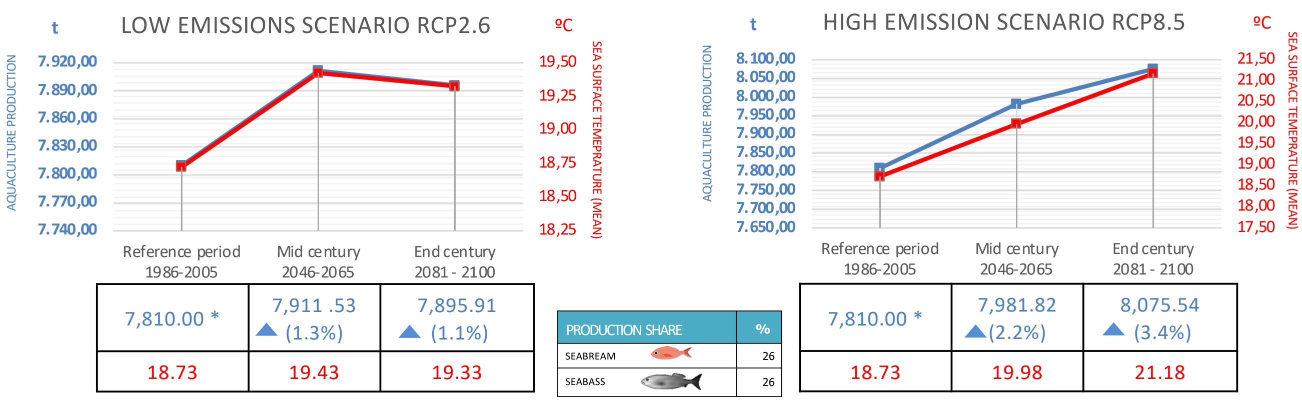


Figure 3.30. Estimations of changes in aquaculture production (tons), due to increased sea surface temperature.

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

3.5.3. Energy

Climate change may impose welfare reductions to the European islands' societies by affecting thermal comfort. Cooling Degree Days (CDD) are a measure of how much (in degrees), and for how long (in days), outdoor air temperature is higher than 21 °C. The CDD is used as a measure of the energy needed to cool buildings. The increase in CDD and the energy demand (GWh/year) for cooling are estimated for the islands under different scenarios of global climate change.

Under the high emissions scenario, it is expected that the CDD[2] increase to 665 CDD, approximately. Under this situation, the increase in cooling energy demand is expected to be 265 % (see **Figure 3.31**).

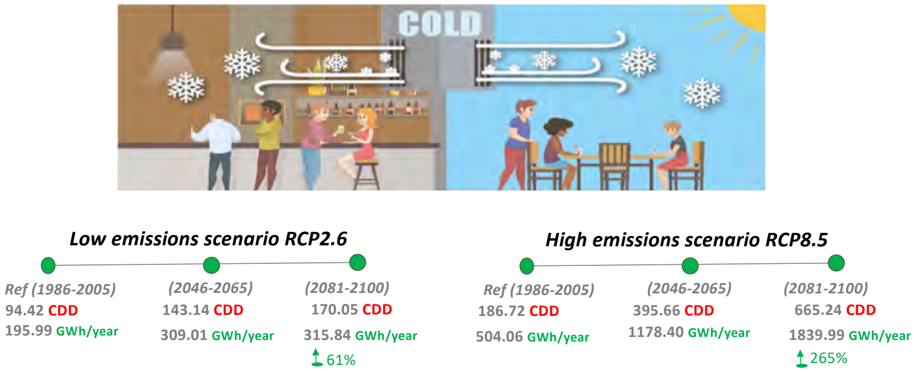


Figure 3.31. Estimations of increased energy demand for cooling in Canary Islands under different scenarios of climate change until 2100.

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from Climate Change impacts to GEM-E3-ISL and GINFORS models.

The Standardized Precipitation Evapotranspiration Index (SPEI) is analysed as a representative indicator for increases in water demand for islands' residents, tourists and agriculture, while it also provides an indication on the available water stored in dams or underground resources. To estimate the increase of energy demand due to the increase in water demand, it was assumed that most of the islands will have to produce desalinated seawater (or groundwater) to meet further increases of demand. Thus, the estimation of the increase in energy demand (GWh/year**)** to produce more drinking water has been done based on the energy consumption required to desalinate seawater.

Under the high emissions scenario (RCP8.5), the situation could be critical as the indicator reach the highest levels, which could lead to an increase of 206 % in desalination energy demand (see **Figure 3.32**).

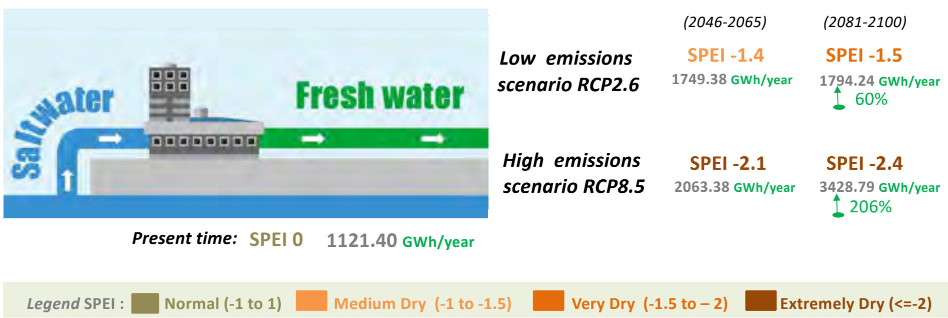


Figure 3.32. Estimations of increased energy demand for desalination in Canary Islands under different scenarios of climate change until 2100.

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from Climate Change4impacts to GEM-E3-ISL and GINFORS models.

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2 The indicator is computed by multiplying the number of days exceeding the threshold by the difference in temperatures.

Maritime Transport

For maritime transport, it has been estimated the impact of Sea Level Rise on ports' operability costs of the islands. The costs have been calculated with reference to 1 meter; this is, the investment needed to increase the infrastructures' height by 1 meter. There is not necessarily a strict correspondence between the SLR and the required elevation of port infrastructures, which also depends on the coastal hydrodynamic and the shape of dikes of each port. By experts' recommendation, we have assumed that 1 meter increase in port height is required to cope with the SLR under RCP8.5 scenario of emissions. Extrapolation for other RCP scenarios is then conducted based on proportionality.

The starting point was the identification of the principal ports in each island (economic relevance). Second, the analysis of the different port areas (exterior, ramps, oil, etc.), and their uses. Third, the elevation costs were estimated per each area and port separately (considering 1 meter elevation). Thus, the costs of 1 meter elevation presented are the sum of all areas and ports analysed, and including the rest of the ports of the island (if applicable) based on proportionality. Estimations consider that all ports areas of the entire area should be elevated at the same time. In other words, the economic values can be interpreted as the depreciation (amortization) costs of the investment needed to increase all ports' infrastructures in the island for 125 years time horizon. No discount rate has been applied.

As expected, the rising of sea levels will affect the sector, as new investments will be needed to keep ports' operability. Under the high emissions scenario, it is expected that these costs could increase 16 million euros per year until the end of the century (see **Figure 3.33**).

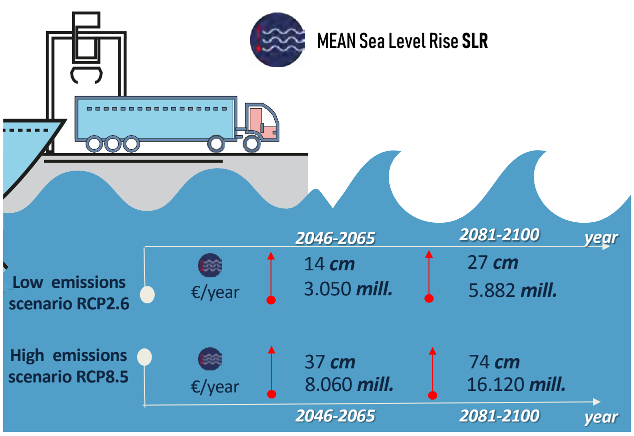


Figure 3.33. Increased costs for maintaining ports' operability in Canary Islands under different scenarios of SLR caused by climate change until 2100.

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

3.6. Impacts on the Island's Socio-Economic System

The aim of our study is to assess the socio-economic impacts of biophysical changes for Canary Islands. For this purpose, we have used the GEM-E3-ISL model, a single-region, multi-sectoral general equilibrium model based on the principles of neo-classical theory, and GINFORS, a macro-econometric model based on the principles of post-Keynesian theory.

Both models include 14 sectors of economic activity, with an emphasis on services and specifically on those composing the tourism industry. The GEM-E3-ISL model also includes endogenous representation of labor and capital markets as well as bilateral trade flows by sector.

Changes in the mean temperature, sea level and precipitation rates are expected to affect energy consumption, tourism flows and infrastructure developments. These impact-chains have been examined and quantified under two emission pathways: RCP2.6, which is compatible with a temperature increase well below 2 °C by the end of the century, and RCP8.5, which is a high-emission scenario. The impact on these three factors was used as input in the economic models, which then assess the effects on GDP, consumption, investments, employment, etc.

In total, 18 scenarios have been quantified for Canary Islands. The scenarios can be classified in the following categories:

1. Tourism scenarios: these scenarios examine the reduction in tourism revenues due to changes in human comfort as captured by the hum-index, the degradation of marine environment, the increased risk of forest fires and beach reduction. The aggregate tourism scenario (TOUR-SC6) assesses the economic impacts of a simultaneous change of all (the above-mentioned) factors.
2. Energy scenarios: the aggregate energy scenario (ENER-SC3) assessed the impacts on regional economic performance of increased total electricity demand driven by cooling and water desalination demand.
3. Infrastructure scenario: this scenario assesses the impact of port infrastructure damages (INFRA-MAR).
4. Aggregate scenarios: these scenarios examine the total impact of the previous-described changes in the economy.

In the aggregate scenario we examine the impacts of a simultaneous change in electricity consumption, tourism revenues and infrastructure damages. The scenario specifications for the two climatic variants are presented below (see **Table 3.7**).

The theoretical and structural differences of the two models mean that this study produces is a reasonable range of impacts, given the uncertainty embodied in economic analysis and especially in the long-term.

In GEM-E3-ISL, the economy is in equilibrium at each point in time. Prices adjust to ensure that supply equals demand (market clearing), and capital is fully used; however, the model allows for equilibrium unemployment as it takes into account labor market rigidities. The impacts are driven mainly

Table 3.7. Aggregate scenario –inputs.

	Tourism revenues (% change from reference levels)	Electricity consumption (% change from reference levels)	Infrastructure damages (% of GDP)
RCP2.6 (2045-2060)	-10.01	6.00	-0.39
RCP2.6 (2080-2100)	-12.81	13.60	-0.43
RCP8.5 (2045-2060)	-12.64	9.00	-1.03
RCP8.5 (2080-2100)	-18.47	34.20	-1.17

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

by the supply side through changes in production costs which influence relative prices; hence, competitiveness and trigger substitution effects and costs of production. The GEME3-ISL model assesses the impacts on the economy up to 2100.

The macro-econometric type of models, such as GINFORS, do not require that all markets are in equilibrium; idle capital and involuntary unemployment are some other features of this type of models where the results are driven mainly by adjustments in the demand side of the economy. The GINFORS assesses the impacts on the economy up to 2050.

With respect to GDP, the estimated change compared to the reference case is between -2.6% and -3.8% in the RCP2.6 in 2050 and between -5.7% and -6.2% in the RCP8.5. The cumulative change over the period 2040-2100 is estimated (by GEM-E3-ISL) to be equal to -4.2% in the RCP2.6 and -9.7% in the RCP8.5 (see **Figure 3.34**).

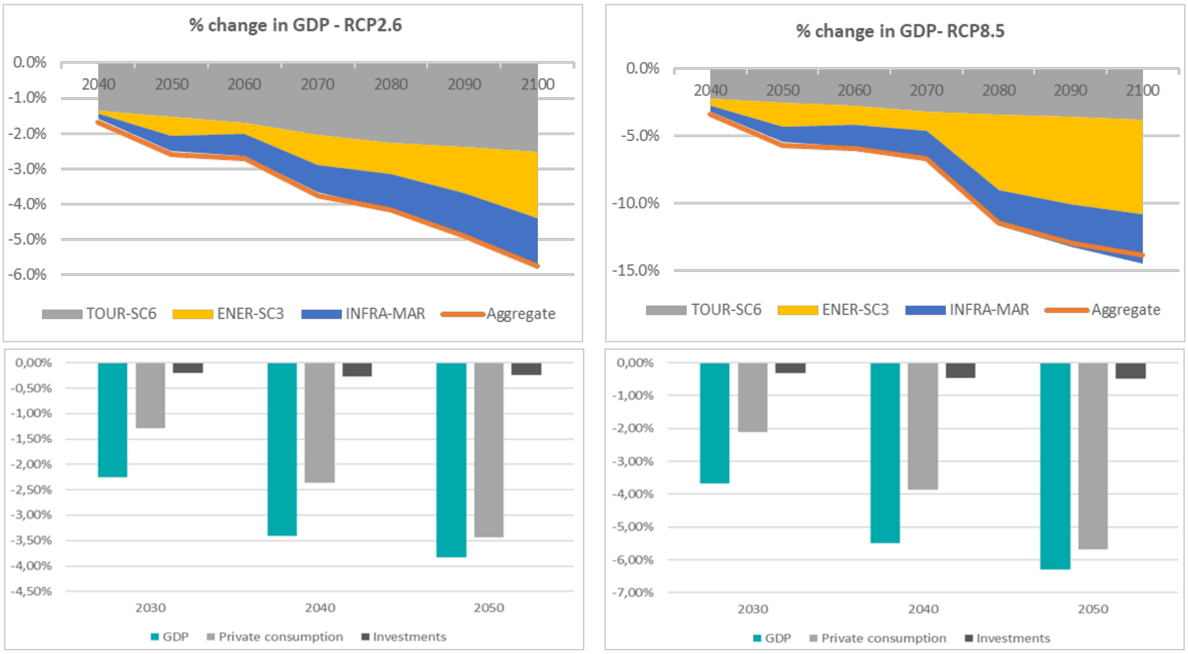


Figure 3.34. Percentage Change in GDP. GEM-E3-ISL results (above), GINFORS (below).

Source: own calculation.

With respect to sectoral impacts, both models show a significant decrease in the activity of tourism related sectors and an increase in the activity of the manufacturing sector, consumer goods industries and agriculture, as a response to relative price changes induced by labor or transportation cost differentials (see **Figure 3.35**).

Overall employment falls in the economy and especially in tourism related sectors following the slowdown in domestic activity. In GEM-E3-ISL, increases in employment in non-tourism related activities are associated with labor costs reductions (as wages fall and their competitiveness increases) and a consequent substitution of capital with labor in other sectors. Employment falls on average by 5.0% in the RCP2.6 and by 8.7% in the RCP8.5 (see **Figure 3.36**).

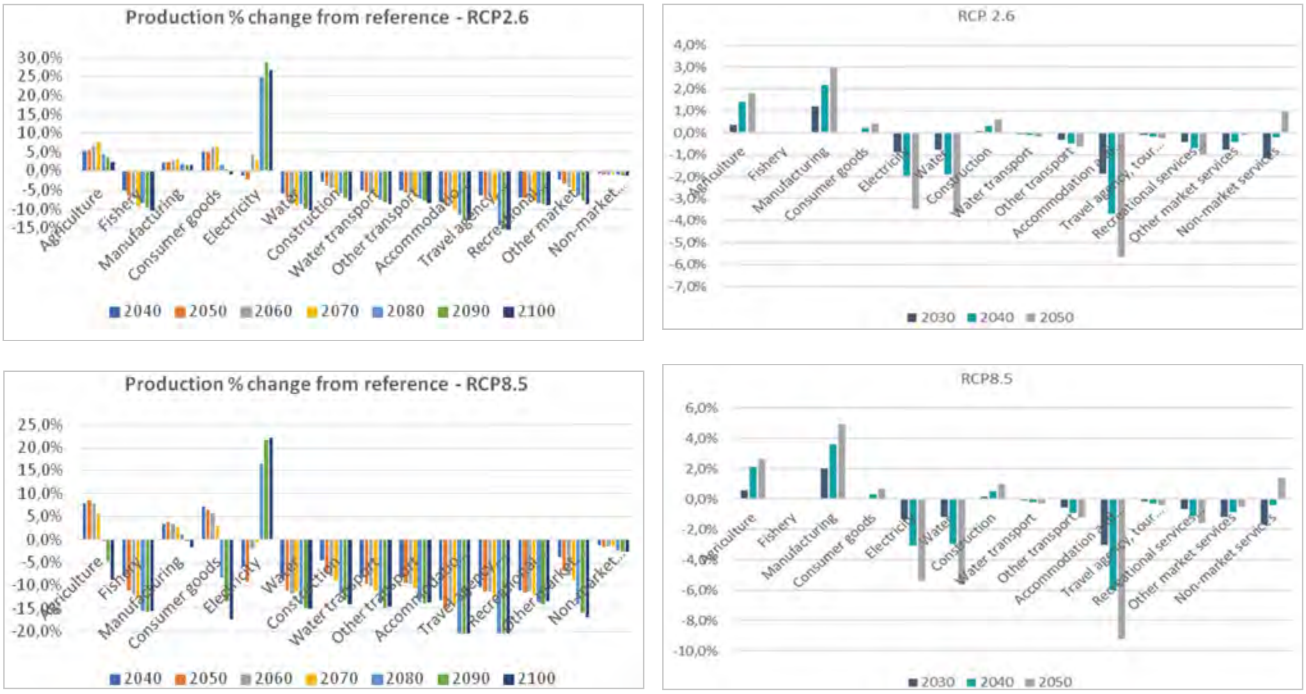


Figure 3.35. Production percentage change from reference GEM-E3-ISL results (above), GINFORS (below).

Source: own calculation.

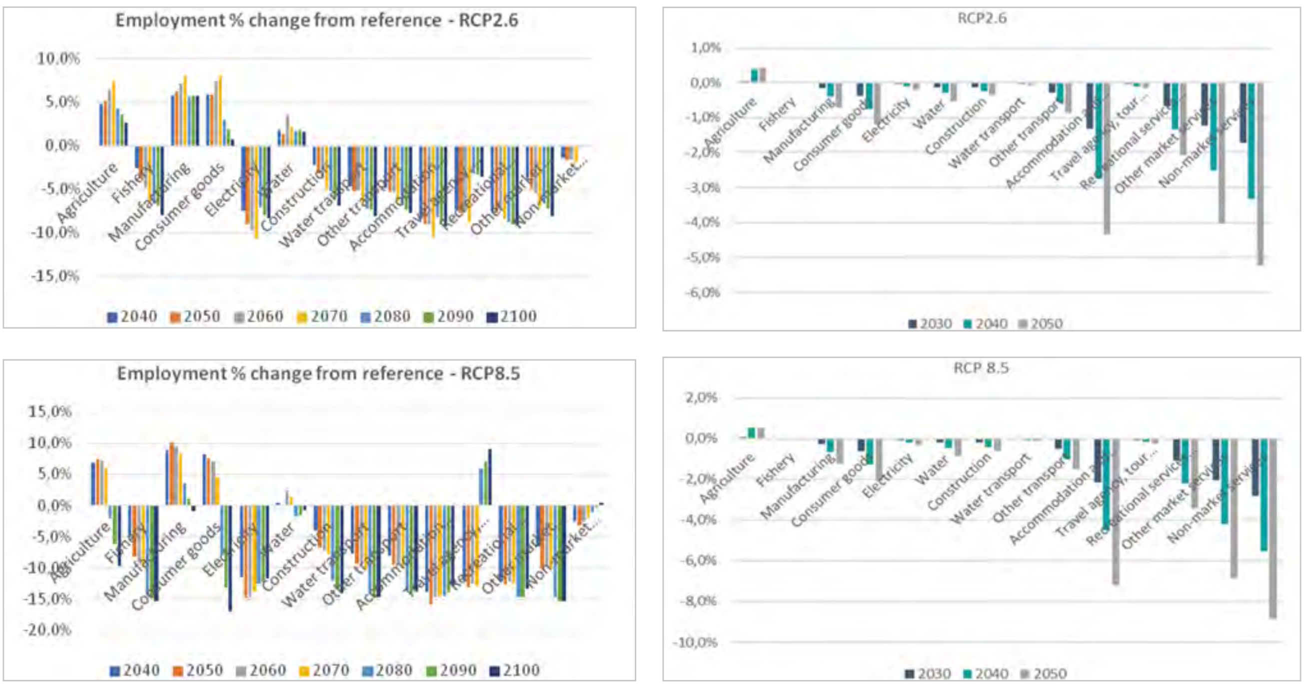


Figure 3.36. Employment percentage change from reference GEM-E3-ISL results (above), GINFORS (below).

Source: own calculation.

3.7. Towards Climate Resiliency

There exists a document called "Canary Islands Strategy to Fight Against Climate Change" (*Estrategia canaria de lucha contra el cambio climático-2012*), which was elaborated by the Canary Agency for Sustainable Development and Climate Change (*Agencia Canaria de Desarrollo Sostenible y Cambio Climático*). This agency was active between 2009 and 2012, when it was extinguished by decree.

There exists a committee of experts advising the Regional Government (belonging to the executive power) which has at its disposal technical sub-committees in charge of these specific issues, but the information related to its activity should be provided by the Regional Government.

Between 2015 and 2018, the Executive Regional Government power announced the setting up of the Canary Islands Observatory of Climate Change (*Observatorio Canario de Cambio Climático*), an organism which creation was proposed in 2015 by the Cabildo de Lanzarote (Island Authority hall of Lanzarote). However, the regulation of this institution hasn't been provided yet, and it does not dispose of specific personnel yet.

In 2020, the ¨Minister of Ecological Transition, fight against climate change and territorial planning¨ lauched preliminary drafts of a climate change law and an updated version of the Canary Islands Strategy to Fight Against Climate Change. Both documents are currently at the stage of public consultation (https://www.gobiernodecanarias.org/cmsgobcan/export/sites/participacionciudadana/iniciativas/.docs/ctelccpt/Anteproyecto-de-Ley-4-11-2020.pdf).

Thanks to the Island Authority hall (Cabildo), the island of Gran Canaria is leading the process, and has activated the passing and implementation in the Governing Council of its action plan, whose horizons and objectives are set for 2030-2050. In addition, Gran Canaria has developed and executed numerous initiatives in the last three years. It has promoted several projects with the Spanish government (*OECC – Oficina Española de Cambio Climático*), the *Fundación Biodiversidad*, the convention of United Nations for Climate Chante (UNFCC), the European Commission (Joint Research Centre), and numerous collectives and social agents of the island.

The Cabildo Island Authority of Gran Canaria has promoted, with support of the Canary Islands Institute of Technology, in parallel, in the previous two years (2017-2018), the adherence of the island's municipalities to the EC initiative of the Covenant of Mayors, and the development of the Strategic Energy and Climate Action Plans (SECAPs) and Plans for Climate and Sustainable Energy (*Planes de Acción por el Clima y la Energía Sostenible*, PACES). 10 of all the 21 municipalities of the island have their own action plans (SCEAPs), and their inventory of greenhouse gas emission to work on its the progressive reduction of CO_2 emission in the coming years. The other 11 municipalities are in the process of elaborating their SECAPs. Finally, the Island Authority (Cabildo) of Gran Canaria has worked since 2017 together with the *Agencia Estatal de Meteorología* (AEMET) to sign a specific agreement about Adverse Meteorological Events (*Fenómenos Meteorológicos Adversos*, FMA) in Gran Canaria. On the other hand, in the framework of the INTERREG MAC programme a project was elaborated and presented by the Island Authority (Cabildo) of Gran Canaria in 2018 to work in the Macaronesian area on climate change (other participants: AEMET, OECC, Governments of Senegal, Mauritania and Cabo Verde, ULPGC, Cabildo de El Hierro, Lanzarote and Tenerife).

Specific limits and obstacles

There is the need for more multilevel governance, and the strongest main limitation faced is the lack of commitment of the regional government regarding this issue. A group of experts (*Grupo de Acción Climática de Gran Canaria*) wrote a roadmap, which was not implemented afterwards.

Moreover, the strategies are carried out at island level, meaning that in many cases there is no consensus or homogenization of the topic in the different islands. For instance, the Island Authority (Cabildo) of Gran Canaria cooperates with the Canary Islands Institute of Technology in the elaboration of the SECAPs for its municipalities, and collaborate with the national agency of meteorology (AEMET), while other islands are not addressing the problem (HERE).

According to an expert in this issue, "the most important and severe limitation is the lack of political willingness to design and address a strategic plan that allows to have:

a) An updated strategy regarding the impacts in all productive sectors to promote adaptation policies.

b) An updated strategy regarding emissions in all sectors to promote mitigation policies about greenhouse gas emissions, with the aim of working on the EU and IPCC proposals (reduce emissions about 45% in 2030 based on 2010's registration, and by 100% in 2050".

Other entities of the Canary Islands, such as the Canary Islands Institute of Technology (ITC), Universidad de La Laguna, Universidad de Las Palmas de Gran Canaria, WWF, ITC, PLOCAN, Centro UNESCO Gran Canaria, Asociación Domitila, Ben Magec-Ecologistas en Acción, Muévete por el Clima, Fundación Orotava de la Ciencia, among others, promote the research and dissemination of climate change impacts. However, there is a weak link between knowledge and decision making, as they are not coordinated with the Regional Government, the 7 island authorities and the 88 municipalities, which may not ensure the efficient implementation in the islands of all the plans addressing climate change. Therefore, better coordination among them is needed.

The problem of an evident lack of high-resolution wave simulations comprising this Atlantic island is a limiting factor for the analysis of climate change impacts. While the Mediterranean region is sufficiently covered by already available wave and surge data, available wave climatology over the Atlantic Ocean has too low resolution. As a result, there is no good source of regional climate model (not included in the MENA-CORDEX). Stakeholders should be made aware that uncertainty is an inherent characteristic of climate data, and that any future planning must cope with it.

There is also a lack of reliable statistics and information related to exposure and vulnerability of the island to climate change. These are important components that worsen climate risks and respond to human interventions (more pressure), in particular, the lack of operational mapping of the main risks to coastal tourism and other sectors of the blue economy. The island' s adaptation focus should be, first, the development of reliable information systems for the periodic monitoring of these components.

3.7.1. Policy Recommendations

A stakeholders consultation process was carried out in the island, aiming to propose, analyse and rank alternative adaptation measures for the island. The profile of the individuals participating in these focal groups involved policy and decision-makers, practitioners, non-governmental and civil society organisations, science experts, private sector, business operators and sector regulators at island level.

The main aim of these meetings was:

1. Identify and present the characterized packages of adaptation and risk management options for the island.
2. Develop detailed integrated adaptation pathways in three timeframes: Short term (up to 2030), Mid-century (up to 2050) and End-century (up to 2100).
3. Evaluate and rank adaptation options for 4 blue economy sectors in the island (energy, maritime transport, aquaculture and tourism).

To this aim, stakeholders utilized five evaluation criteria to rank the proposed measures:

- Cost efficiency: Ability to efficiently address current or future climate hazards/risks in the most economical way.
- Environmental protection: Ability to protect the environment, now and in the future.
- Mitigation win-wins and trade-offs: Current ability to meet (win-win) or not (trade-off) the island / archipelagos mitigation objectives.
- Technical applicability: Current ability to technically implement the measure in the island.
- Social acceptability: Current social acceptability of the measure in the island.

Four scenarios of intervention were analysed, called Adaptation Policy Trajectories which are different visions of future policy adaptation choices:

- APT A Minimum Intervention - Low investment, low commitment to policy change.
- APT B Economic Capacity Expansion - High investment, low commitment to policy change.
- APT C Efficiency Enhancement - Medium investment, medium commitment to policy change.
- APT D System Restructuring - High investment, high commitment to policy change.

It was assumed that adapting to climate change may range from minimal to high cost, and from requiring a small or incremental change to a significant transformation from the *status quo*. However, not all APT scenarios were considered in all islands, especially when their stakeholders had a clear vision on the types of measures with greatest viability. Therefore, the final set of proposed adaptation measures are framed in the islands' socio-economic and political context, have a sectoral perspective, and respond to the islands' future scenarios of climate change. At the same time, the involvement of regional stakeholders in policy design allows them to engage in the effective implementation of climate actions on their island.

In Appendices from K to N, a brief explanation of each adaptation option can be found, classified by type or class: Vulnerability Reduction, Disaster Risk Reduction, Social-Ecological Resilience, and Local Knowledge. The latest group refer to very specific measures proposed by stakeholders in each island to ratify the needs.

3.7.1.1. Tourism

For the Canary Islands, the urgency to respond to water scarcity is considered one of the biggest issues for the future of tourism in the archipelago. While desalination is selected as ideal measure in the short- and medium-term, beach nourishment is considered necessary in the timeframe up to 2100 (long-term) as beaches will have to be nourished due to the impacts of climate change and rising sea levels.

In managing long term risk, coastal protection is the most important for the region throughout the scenarios. However, for APT D, drought and water conservation plans are vital and a priority in the short term; although, it has to be mentioned that both measures are seen as equally important on this APT.

For the disaster response class, the risks related with fire – fire management plans – were considered high in all time periods in the Canary Islands. The pathway clearly reflects the climate-risk context of the region. Pre-disaster early recovery planning was also selected for all time frames, since many future problems could be solved this way and there is still a lot to do in this sense.

Adaptation of groundwater management is considered urgent for the sector in the short-term; however, incorporating monitoring, modelling and forecasting systems for the medium and longer term it is important, since there is still a lot to do in this field.

For APT B and C scenarios, the priority for dune restoration and rehabilitation is ratified by stakeholders. The tourism sector will benefit from the maintenance of dunes as this has a positive impact on tourism, since one of the biggest attractions of the destination are its beaches. However, for APT B, river rehabilitation and restoration are selected for mid and long term, showing again the importance of water for this region.

Cultural services are only considered for the APT C - Efficiency Enhancement (medium investment and medium commitment to policy change scenario). In this case, the region is considered to dedicate efforts in all time frames to preserve and minimize the impacts on biodiversity and ecosystems, while also preserving the attractiveness of the region (adaptive management of natural habitats).

The specific adaptation options for the tourism sector include solutions of various kinds. Where the problem of sewage throughout the archipelago can be clearly seen, zero sewage discharge to the sea is the most urgent adaptation option selected in all APTs. Then, if we take APT C and D, the issue of the huge energy consumption the tourism sector has become clear, as distributed electric grids powered by renewables are also selected as urgent, showing the need this sector has to transform its energy into renewable sources. The problem of wildfires is mainly due to the lack of management and prevention. The measure consisting on forest fire prevention emphasises the importance of prevention rather than action to extinguish the fire, which would be a much more effective measure. This one is clearly emphasized in all APTs. Then, bottom-up managed marine protected micro-areas appear to be important, due to the value the coastal resources have for the islands both for their inhabitants and for the attractiveness to tourists. Even if it has been selected for the long term, the issue of waste is also a major problem on the islands, especially the challenge of properly managing organic waste. In particular, in APT A and B, residual organic matter composting to reduce methane emissions has been highlighted for the short and medium term. Ultimately, even if passive, low carbon adaptation of tourist buildings has not been selected in any scenario, it does not mean it is not important, but having to choose among six options for three scenarios, shows the priority other measures have (see **Table 3.8**).

Table 3.8. Proposed adaptation options for tourism in Canary Islands.

<table>
<tr><td rowspan="7">APT A – Pathway
—
Minimum Intervention
low investment, low commitment to policy change
—
This policy trajectory assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td>Activity and product diversification</td><td colspan="2">Public awareness programmes</td></tr>
<tr><td colspan="2">Coastal protection structures</td><td>Drought and water conservation plans</td></tr>
<tr><td colspan="3">Fire management plans</td></tr>
<tr><td>Post-disaster recovery funds</td><td colspan="2">Pre-disaster early recovery planning</td></tr>
<tr><td>Adaptation of groundwater management</td><td colspan="2">Monitoring, modelling and forecasting systems</td></tr>
<tr><td>Zero sewage discharge to the sea</td><td>Residual organic matter composting</td><td>Forest fire prevention</td></tr>
<tr><td rowspan="9">APT B – Pathway
—
Economic Capacity Expansion
high investment, high commitment to policy change
—
This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td>Economic Policy Instruments (EPIs)</td><td colspan="2">Financial incentives to retreat from high-risk areas</td></tr>
<tr><td>Activity and product diversification</td><td colspan="2">Public awareness programmes</td></tr>
<tr><td colspan="2">Desalination</td><td>Beach nourishment</td></tr>
<tr><td colspan="2">Coastal protection structures</td><td>Drought and water conservation plans</td></tr>
<tr><td>Adaptation of groundwater management</td><td colspan="2">Monitoring, modelling and forecasting systems</td></tr>
<tr><td>Dune restoration and rehabilitation</td><td colspan="2">River rehabilitation and restoration</td></tr>
<tr><td>Zero sewage discharge to the sea</td><td>Residual organic matter composting</td><td>Forest fire prevention</td></tr>
<tr><td rowspan="11">APT C – Pathway
—
Efficiency Enhancement
medium investment, medium commitment to policy change
—
This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td>Public awareness programmes</td><td colspan="2">Activity and product diversification</td></tr>
<tr><td>Tourist awareness campaigns</td><td colspan="2">Local circular economy</td></tr>
<tr><td colspan="3">Water restrictions, consumption cuts and grey-water recycling</td></tr>
<tr><td colspan="3">Coastal protection structures</td></tr>
<tr><td colspan="3">Mainstreaming Disaster Risk Management</td></tr>
<tr><td colspan="3">Monitoring, modelling and forecasting systems</td></tr>
<tr><td colspan="3">Dune restoration and rehabilitation</td></tr>
<tr><td colspan="3">Adaptive management of natural habitats</td></tr>
<tr><td>Zero sewage discharge to the sea</td><td>Forest fire prevention</td><td>Residual organic matter composting</td></tr>
<tr><td rowspan="8">APT D – Pathway
—
System Restructuring
high investment, high commitment to policy change
—
This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td colspan="3">Economic Policy Instruments (EPIs)</td></tr>
<tr><td>Public awareness programmes</td><td colspan="2">Activity and product diversification</td></tr>
<tr><td colspan="3">Water restrictions, consumption cuts and grey-water recycling</td></tr>
<tr><td>Drought and water conservation plans</td><td colspan="2">Coastal protection structures</td></tr>
<tr><td colspan="3">Pre-disaster early recovery planning</td></tr>
<tr><td colspan="2">Adaptation of groundwater management</td><td>Monitoring, modelling and forecasting systems</td></tr>
<tr><td>Zero sewage discharge to the sea</td><td>Distributed electric grids powered by renewables</td><td>Residual organic matter composting</td></tr>
</table>

Vulnerability Reduction · *Disaster Risk Reduction* · *Socio-Ecological Resilience* · *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

3.7.1.2. Maritime transport

The Canarian maritime transport sector is quite clear on its priorities when considering social dialogue for training as a measure of Vulnerability Reduction, since it is much more important for the port to train the port sector on how to act.

Refrigeration, cooling and ventilation systems are also preferred measures, since keeping passengers, employees and goods in good thermal conditions is of vital importance for the operation and good service of the port.

For management of long-term disaster risks, climate proof ports and port activities are clearly seen as the priority. Climate change risks have to be analysed to better adapt and prepare for those impacts. All investments must take climate change into account before moving forward with them.

In terms of preparedness, it is of great urgency to implement Early Warning Systems (EWS) and climate change monitoring, being one of the most important immediate and easiest measures to be implemented. Having that information, enables to make a decision on how to deal with these changes and act on the different infrastructures depending on what that alert tells.

Provisioning services will focus initially on marine life friendly coastal protection structures and, for the long-term, combined protection and wave energy infrastructures. Protecting marine life is essential, but then it is important to ensure that this infrastructure can be productive from the investments that are made.

Local Knowledge options are mainly focused on coastline and infrastructure protection, reflecting how having safe and operational ports is of paramount importance for the Canarian maritime transport sector. Therefore, adapting infrastructure to climate threats and encouraging the adaptation of recreational marinas to the main climate change hazards are key measures that should be implemeted by adapting mooring structures and related services, especially the electrical connection to ships during the stay in port (cold ironing), to climatic threats, and particularly to the rise in sea level, so as to enable the Canary Islands to maintain and improve their position in international recreational cruise traffic, as well as for recreational marinas.

After the tourism sector (direct and indirect), only the sub-sectors that we include in the blue economy, especially port activity and maritime transport, have a significant weight in the region's GDP (around 7 %). This means that preparing and strengthening these sectors in the face of the threat of climate change is key for the Islands. Therefore, to plan the expansion of the port linked to the locational rent of the island in areas not exposed to risks is also important from the point of view of diversification of the Canarian economy, since the actions that strengthen the competences of the Canary Islands in the territorial waters (as defined in the new statute) are of fundamental importance, planning with climate security (areas not exposed to risks) the expansion of the port area to accommodate new and more activity related to the opportunities offered by the special regimes of the Canary Islands (RUP, ZEC, Registry of ships (REBECA), with special attention to mobility and the relationship between the port and the city.

Then, improving and ensuring operational safety in ship repair aims to improve and guarantee the operational safety of ship repair activity against climatic events, including shipyards and workshops with deep-sea repair capacity. Also, transfering knowledge and capacities for the adaptation to climate change of nearby west African ports will guarantee their future connectivity with the Canary Islands and the development of the potential of maritime navigation between the Canary Islands and North-West Africa. Lastly, strengthening and improving import bunkering facilities are also selected as imperative measures in order to favour the transition to the use of new fuels and the electrical connection to the ships, since the bunkering activity is one of the most important activities the Canarian ports. This initiative would include cutting edge solutions in the adoption of bunkering facilities to power renewable energy-based technologies (see **Table 3.9**).

Table 3.9. Proposed adaptation options for maritime transport in Canary Islands.

<table>
<tr><th rowspan="10">APT C – Pathway
—
Efficiency Enhancement
medium investment, medium commitment to policy change
—
This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system</th><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td colspan="3">Social dialogue for training in the port sector</td></tr>
<tr><td colspan="3">Diversification of trade using climate resilient commodities</td></tr>
<tr><td colspan="3">Refrigeration, cooling and ventilation systems</td></tr>
<tr><td colspan="3">Climate proof ports and port activities</td></tr>
<tr><td colspan="3">Early Warning Systems (EWS) and climate change monitoring</td></tr>
<tr><td colspan="2">Marine life friendly coastal protection structures</td><td>Combined protection and wave energy infrastructures</td></tr>
<tr><td>Coastal protection structures</td><td colspan="2">Hybrid and full electric ship propulsion</td></tr>
<tr><td colspan="3">Integrate ports in urban tissue</td></tr>
<tr><td>Adapt infrastructure to climate threats</td><td>Adaptation of recreational marinas to the main dangers derived from climate change</td><td>Improve and ensure operational safety in ship repair</td></tr>
</table>

Vulnerability Reduction | *Disaster Risk Reduction* | *Socio-Ecological Resilience* | *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

3.7.1.3. Energy

Financial support for smart control for energy in houses and buildings has been selected by stakeholders in both APTs (B and D) for all time frames. This is done due to the fact that financial support is needed with regard to the digitalisation of buildings (intelligent buildings), in order to modify the structure of an existing building to lower the energy demand.

Stakeholders agree on the importance of green jobs and businesses. These being able to support the Canaries reliance on adaptation energy issues while serving as a form of economic diversification, reducing the actual dependency on the tourism sector.

Small scale production and consumption were selected in all time frames, with the idea of empowering local consumers before large companies, in order to be more resilient to the effects of climate change. On this one, the adaptation options are available only under the APT C – Efficiency Enhancement.

Energy storage systems chosen as storage are crucial for energy services reliability and decarbonization objectives, since they will be key to the development and penetration of renewable energy.

For Disaster Risk Reduction, and to manage long term risk, the decisions need to be sensible to the level of investment and reflect the climate change risk identified for the region. Except for APT D, that clearly selects upgrade evaporative cooling systems for all time frames, both APT B and C, consider reviewing building codes of the energy infrastructure as a priority in the short and medium term.

Energy efficiency in urban water management (E3) is urgent for the sector in all time frames, as it is more oriented to other environments where thermal consumption does exist, showing again the need to respond to the growing problem of water scarcity in the archipelago. Underground piping for cooling can be a difficult energy resource concept to grasp and to account for in energy planning. However, APT B selects underground tubes and piping in urban planning for the longer term, perhaps because of the future improvement of this technology.

Regulating and maintenance services are considered only for APT B and C scenarios, where the priority for biomass power from household waste is shown, with the aim of taking advantage of all that can be done without affecting the ecosystem. Then, for the medium and long term, urban green corridors are selected in order to decrease energy efficiency, which cannot be done overnight, contrary to the first one.

The specific adaptation options for the energy sector include solutions of various kinds. If we take APT C and D, promoting cogeneration and micro smart grids are categorized as urgent. These show the importance of having a greater resilience, since in the event of possible power failures in the electrical system, they will always have a guaranteed power supply. Then, the low and high enthalpy geothermal energy also gives stability to the electrical network. This is explained by the fact that the Canary Islands are isolated energy systems, each island generating its own electricity. Therefore, these measures are of the utmost importance to prevent run out of energy.

The difference comes when APT D, which aims to transform the current social-ecological and economic system, supports shared self-consumption facilities to encourage the shared use of facilities in order to share costs and maximize the efficiency and management capacity of these facilities, while APT C focuses on hydrogen as energy vector, with the aim of using the renewable effluents for hydrogen production. The hydrogen could then be used after storage in high-pressure tanks as vehicle fuel, especially for heavy mobility. Renewable technology hybridization is considered relevant to ensure a balanced electrical system and guarantee quality supply. For example, if photovoltaic technology means that energy is only available during daylight hours, other technologies such as wind power should be used proportionally to cover what photovoltaic technology cannot. Lastly, micro smart grids, could be used with the aim of providing greater resilience, since in the event of possible power failures in the electrical system, power supply will always be guaranteed. (see **Table 3.10**).

Table 3.10. Proposed adaptation options for the energy sector in Canary Islands.

<table>
<tr><th rowspan="8">APT B – Pathway
—
Economic Capacity Expansion
high investment, low commitment to policy change
—
This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy</th><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td colspan="3">Financial support for smart control of energy in houses and buildings</td></tr>
<tr><td>Green jobs and businesses</td><td colspan="2">Public information service on climate action</td></tr>
<tr><td colspan="3">Demand Side Management (DSM) of Energy</td></tr>
<tr><td colspan="2">Review building codes of the energy infrastructure</td><td>Upgrade evaporative cooling systems</td></tr>
<tr><td colspan="2">Energy efficiency in urban water management</td><td>Underground tubes and piping in urban planning</td></tr>
<tr><td>Biomass power from household waste</td><td colspan="2">Urban green corridors</td></tr>
<tr><td>Hydrogen as energy vector</td><td>Renewable technology hybridization</td><td>Micro smart grids</td></tr>
</table>

Table 3.10 (Cont.). Proposed adaptation options for the energy sector in Canary Islands.

<table>
<tr><td rowspan="12">APT C – Pathway
—
Efficiency Enhancement
medium investment, medium commitment to policy change
—
This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td colspan="3">Green jobs and businesses</td></tr>
<tr><td colspan="3">Small scale production and consumption (prosumers)</td></tr>
<tr><td>Collection and storage of forest fuel loads</td><td colspan="2">Energy storage systems</td></tr>
<tr><td colspan="2">Review building codes of the energy infrastructure</td><td>Upgrade evaporative cooling systems</td></tr>
<tr><td colspan="3">Grid reliability</td></tr>
<tr><td colspan="3">Energy efficiency in urban water management</td></tr>
<tr><td>Biomass power from household waste</td><td colspan="2">Urban green corridors</td></tr>
<tr><td colspan="2">Educational garden plots</td><td>Heated pools with waste heat from power plants</td></tr>
<tr><td>Micro smart grids</td><td>Promote cogeneration</td><td>Low and high enthalpy geothermal energy</td></tr>
<tr><td rowspan="8">APT D – Pathway
—
System Restructuring
high investment, high commitment to policy change
—
This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td colspan="3">Financial support for smart control of energy in houses and buildings</td></tr>
<tr><td colspan="3">Green jobs and businesses</td></tr>
<tr><td colspan="3">Energy storage systems</td></tr>
<tr><td colspan="3">Upgrade evaporative cooling systems</td></tr>
<tr><td colspan="3">Energy recovery microgrids</td></tr>
<tr><td colspan="3">Energy efficiency in urban water management</td></tr>
<tr><td>Micro smart grids</td><td>Promote cogeneration</td><td>Low and high enthalpy geothermal energy</td></tr>
</table>

Vulnerability Reduction | *Disaster Risk Reduction* | *Socio-Ecological Resilience* | *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

3.7.1.4. Aquaculture

In the Canary Islands, there are good tax benefits for reinvestment, which have brought about tremendous economic development. Regarding climate change, adaptation stakeholders agree on the importance of awareness campaigns for behavioural change due to the challenge it represents. Aquaculture is based on a biased and deteriorated public perception, due to of preconceived ideas. The industry is already immersed in a communication plan to change this perception.

Addressing consumer and environmental concerns at the local level is essential and was selected in all time frames, since local consumption will not be enough due to the small population, with the idea that aquaculture will progress with exports. Short-cycle aquaculture was also chosen in all time frames. In the private sector, efficiency is what matters, so if cycles are shortened, the sector will be more efficient and make it more productive.

The final class included actions to reduce socio-economic vulnerability is physical capital. In this case, only the APT B – Economic Capacity Expansion is considered. Here again, submergible cages is the preferred option without any doubt in all time frames. Aquaculture is the future if we want to have more fish available to feed the world population.

For Disaster Risk Reduction, and to manage long term risk, the decisions need to be sensible to the level of investment and reflect the climate change risk identified for the region. For both APT B and C, it is important to consider climate proof aquaculture activities as a priority in the short-term, since it is easier to fight the open sea and the big waves than to be close to the land. Then risk-based zoning and site selection for medium and long-term are crucial, since from the point of view of risk, when we concentrate a herd of animals, it is conducive to natural enemies. These exert a greater health risk than economic benefits, so the more dispersion the better.

For APT C, species selection is urgent for the sector in all time frames. However, APT B, which selects feed production for the short and medium-term, is also important, since it has been found that nutrients that fish need can be transformed, finding new alternatives.

Cultural services are only considered for the APT C - Efficiency Enhancement (medium investment and medium commitment to policy change scenario). In this case, it is considered to dedicate efforts in the short and medium term creating educational visits, and then, in the long-term, promoting aquaculture cuisine. Both measures will go hand in hand; it is very important that the A8 is known, but social acceptance is above that. Without social acceptance, there is nothing to do in the Canary Islands. A8 is vital, since the public perception is biased, but in the chiefs, there is a lot of environmental awareness, which will create awareness around consuming local products.

The specific adaptation options for the aquaculture sector include solutions of various kinds. If we take APT C, reformulating the POEM (A30) is identified as the most important. With the aim to address the impact of climate change, the criteria for determining areas to be used in the future needs to be improved and expanded: planning. Increasing depth reduces impact, improves habitats, and increases production, followed by review and streamline administrative processes, since improving governance is key to addressing the impact of climate change. Reviewing and streamlining administrative procedures will help minimize the impact on production volumes. Lastly, favouring the development of offshore aquaculture, which means introducing a cultivation system that does not exist on the islands, improves the resistance to catastrophic weather episodes as a result of climate change and, consequently contributes to reducing the environmental impact, favouring an increase in production.

Regarding APT B, increase POSEI and REF incentives are selected as the most urgent, as they are incentives that compensate for the distance and insularity, followed by knowledge transfer and financial support of emerging industries and promotion of tourist and non-tourist consumption. These incentives are implemented, on the one hand, with the aim of enabling local production of raw materials and juveniles, and the introduction of new species more resilient to climate change and its effects; and, on the other hand, to increase consumption on the islands, which will help to reduce emissions, enhance the zero km concept, contribute to the development of food sovereignty with high quality protein, and strengthen social cohesion. Lastly, both APTs match in the long-term measure (see **Table 3.11**).

Table 3.11. Proposed adaptation options for the aquaculture sector in Canary Islands.

<table>
<tr><td rowspan="9">APT B – Pathway
—
Economic Capacity Expansion
high investment, low commitment to policy change
—
This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td colspan="3">Tax benefits and subsidies</td></tr>
<tr><td colspan="3">Awareness campaigns for behavioural change</td></tr>
<tr><td colspan="3">Submersible cages</td></tr>
<tr><td>Climate proof aquaculture activities</td><td colspan="2">Risk-based zoning and site selection</td></tr>
<tr><td colspan="2">Feed production</td><td>Species selection</td></tr>
<tr><td colspan="3">Selective breeding</td></tr>
<tr><td>Increase POSEI and REF incentives</td><td>Promote tourist and non-tourist consumption</td><td>Knowledge transfer and financial support of emerging industries</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="10">APT C – Pathway
—
Efficiency Enhancement
medium investment, medium commitment to policy change
—
This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td colspan="3">Awareness campaigns for behavioural change</td></tr>
<tr><td colspan="3">Addressing consumer and environmental concerns at the local level</td></tr>
<tr><td colspan="3">Short-cycle aquaculture</td></tr>
<tr><td>Climate proof aquaculture activities</td><td colspan="2">Risk-based zoning and site selection</td></tr>
<tr><td colspan="3">Disease prevention methods</td></tr>
<tr><td colspan="3">Species selection</td></tr>
<tr><td>Best Management Practices</td><td colspan="2">Selective breeding</td></tr>
<tr><td colspan="2">Create educational visits</td><td>Promote aquaculture cuisine</td></tr>
<tr><td>Reformulate the POEM (Zoning)</td><td>Review and streamline administrative processes</td><td>Favour the development of off-shore aquaculture</td></tr>
</table>

Vulnerability Reduction *Disaster Risk Reduction* *Socio-Ecological Resilience* *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop reports.

Chapter

4

Corsica (France)

SOCLIMPACT

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 776661

CONTENTS

Corsica at a Glance

Corsica is an island located in the Mediterranean Sea and a French territorial collectivity. It is the fourth largest island in the Mediterranean, with a surface area of 8,680 km^2 and a population of 325,000 residents. The island is mainly composed of forests (46% of the island) and counts several landscapes and local or endemic specificities. Corsica has experienced the strongest regional growth in France for 20 years (+2.3% average annual GDP growth). The island's economy heavily depends on tourism but is trying to diversify itself (renewable energies, education and sciences, digital startups).

The Blue Economy Sectors

- **Aquaculture**

  Marine aquaculture in Corsica is an interesting sector driven by a dynamic synergy between university (Universita Corsica) and leading regional businesses such as the Gloria Maris group. This sector continues to expand and counts nearly 11 companies making 11 million euros a year, employing 120 people in Corsica. Aquaculture is developed in the eastern plain of the island. In the past three years, the shellfish production has grown by 20%.

- **Maritime Transport**

  The maritime transport is an important and developed sector which ensures "territorial continuity" and allows Corsica to open to international markets. Nearly 26,000 commercial rotations are carried out on the island each year by 2 main companies: Corsica Linea and Corsica Ferries. However, the cruise sector remains the most emitting sector. In 2016, 400,000 tourists arrived in Ajaccio by cruise ships and 40,000 pleasure boats were declared in Corsica.

- **Energy**

  Fossil energy accounts for 40% of Corsica's energy mix. But, this mix depends mainly on imports from Sardinia, Italy (30%) and uses 20% of hydraulic energy. In order to counter this dependence on fossil fuels and imports, Corsica is one of the first territories to have developed a "Renewable Energy Development Program".

- **Tourism**

  Tourism is the most important sector in Corsica. In 2015, 10.6% of the Island's employment and 11% of the GDP were generated by tourist's spending. In addition, the population increases sharply in the summer: 430,000 non-residents in the high season (mid-August) for a population of 320,000 inhabitants. For example, in 2016, Corsica has welcomed over 8.9 million passengers. But the tourism industry is also a major problem on the island, resulting in a high cost of living, long-term rental difficulties due to seasonal offers, high real estate prices and very poorly paid seasonal jobs.

4.1. Current Climate and Risks

The climate of Corsica is generally described as Mediterranean, characterised by hot, dry summers and mild, wet winters. However, there are large temperature variations depending on altitude differences and winds. In fact, Corsica is divided into four climatic zones: Mediterranean Climate (up to 200 m of altitude); Transition Zone (from 200 to 1000 m altitude); Moderate Climate (from 1000 to 1500 m altitude); Alpine Climate (at more than 1500 m altitude).

From 1000 m, the average temperature is below 0 °C. Also, average rainfall is less than 500 mm per year on the coast, can reach 1500 mm at an altitude of 1000 m and 2000 mm in the high mountains.

In summer, the coast is very dry. Thunderstorms are rare, but violent. The average maximum temperatures generally reach 30 °C. In winter, the average minimum temperatures are between 5 and 7 °C, due to the immediate proximity of the Mediterranean. Between October and February, snow falls and often covers the summits until summer (see **Figure 4.1**).

CURRENT CLIMATE-RELATED RISKS

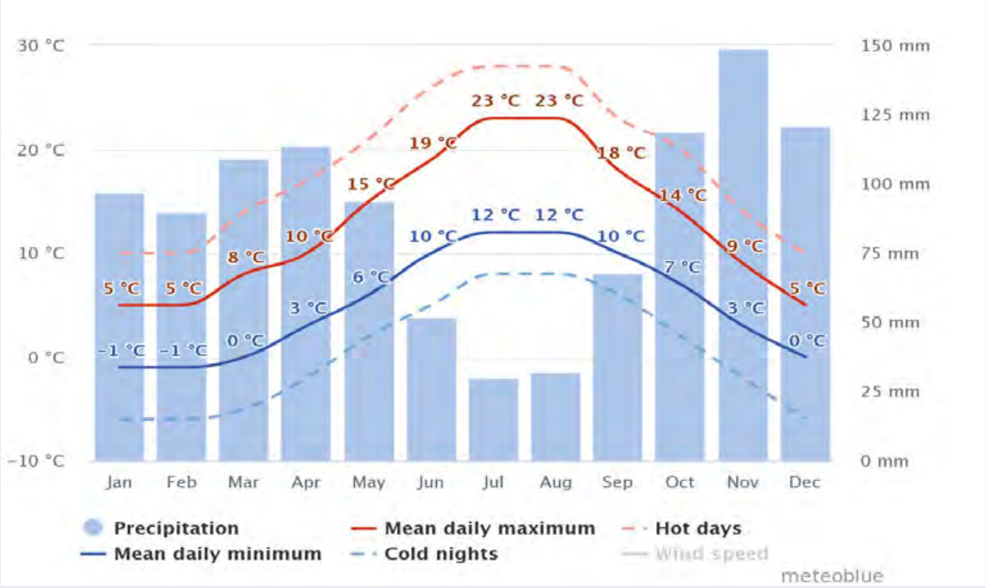
- Coastal flood High
- Wildfire High
- Extreme heat Medium

SIGNIFICANT CLIMATE EVENTS

- Heatwave (summer 2017)
- Drought (2018)
- Rainfall (2008, 2017)
- Floods (2013)

CLIMATE CHARACTERISTICS (41.92°N 8.74°E, 12m asl)

Average temperature and precipitation



Wind speed

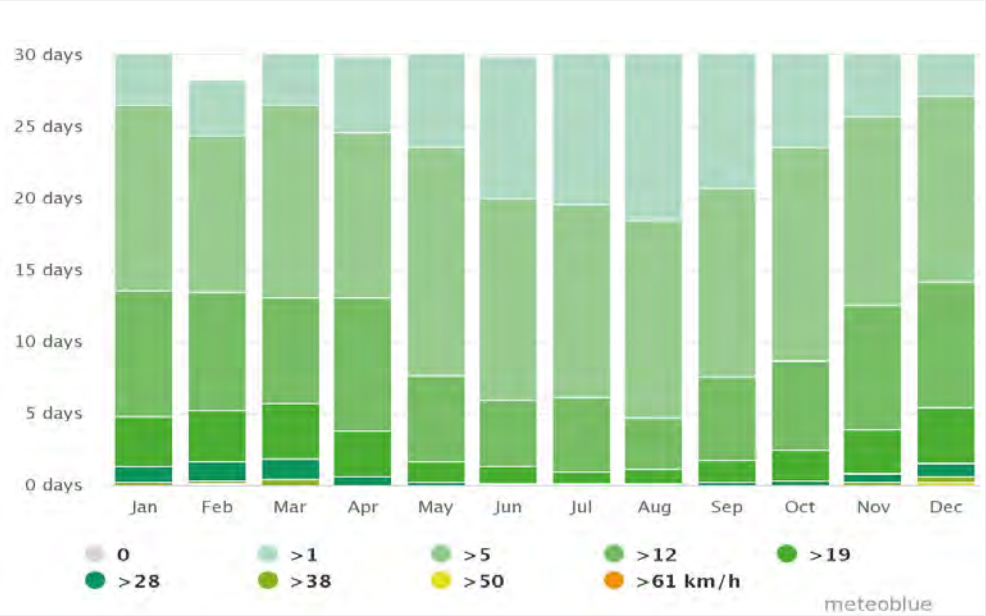
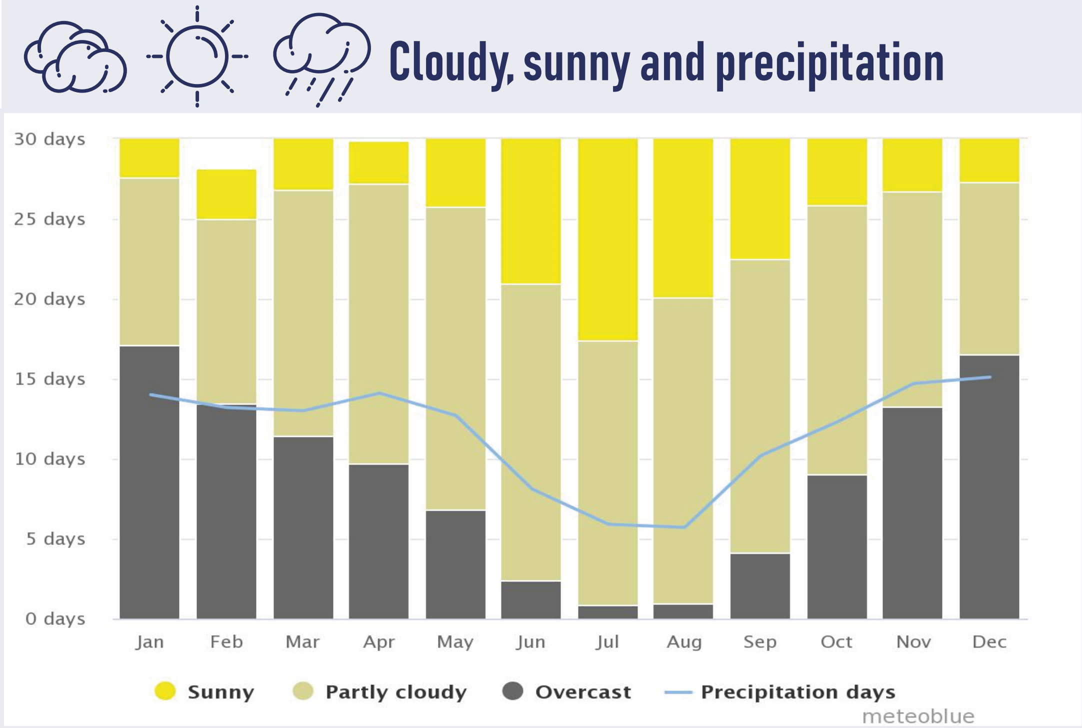


Figure 4.1. Climate factsheet

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System). **(Continued on the next page)**



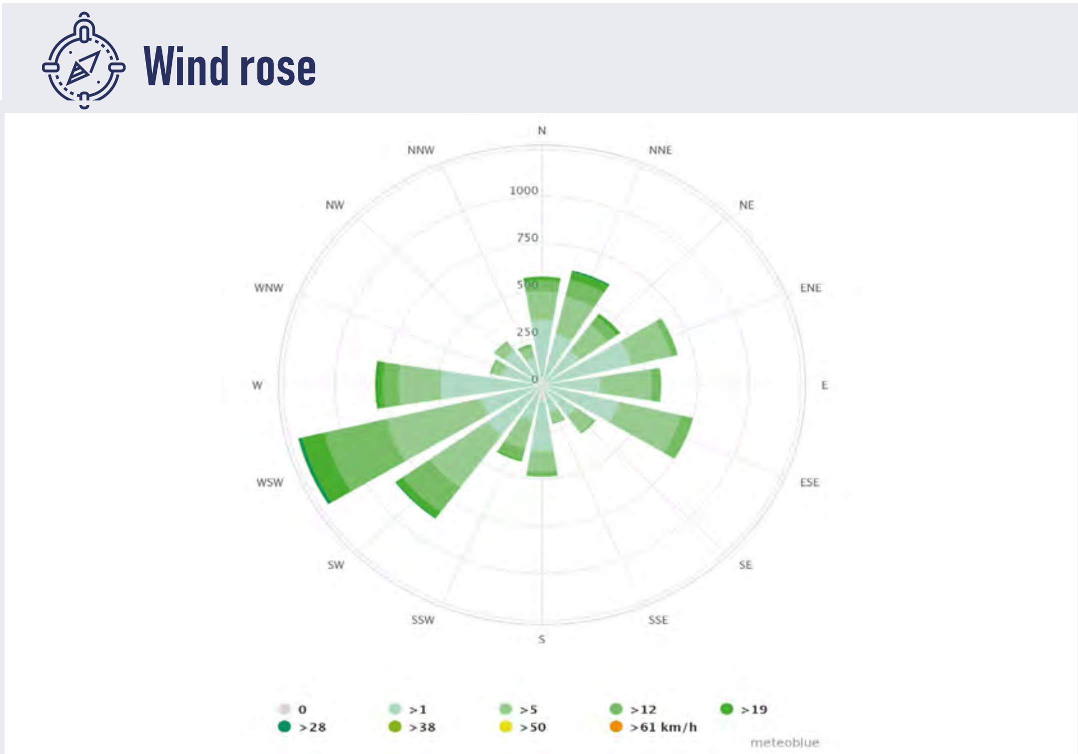


Figure 4.1 (Cont.). Climate factsheet

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System).

4.2. Climate Change Outlook

Climate hazards indicators represent the entry point to understand the climate change exposure of the blue economy sectors. The indicators have been computed for two scenarios, RCP2.6 (low emission scenario) and RCP8.5 (high emission scenario) and for different horizon times namely: a reference period (1965-2005), mid-century (2046-2065) and end of century (2081-2100). Main source of climate projections (future climate) for Corsica is EURO-CORDEX ensemble even if other model sources were applied when required, depending of available scales. Results are presented in form of maps, tables or graphs and only when the information shows an interesting outcome.

4.2.1. Tourism

4.2.1.1. Beach flooding and related losses

One of the consequences of an increase in the mean sea level will be the flooding of coastal areas. This includes sand beaches, which are the main asset for tourism activities in most of the European islands. Therefore, estimating the potential risk of beach loss due to climate change is of paramount importance for the economy of those islands.

The 95th percentile of the flood level averaged was selected as an indicator of interest. The values are presented as anomalies with respect to the present mean sea level at beach location (i.e., including the median contribution of runup). In all cases, an increase is expected being larger at the end of the century under scenario RCP8.5. The values in that scenario is 992.48 cm in Corsica. Under mean conditions, we find that, at end of century, the total beach surface loss range goes from ~38% under scenario RCP2.6 to ~54% under scenario RCP8.5 (see **Figure 4.2**).

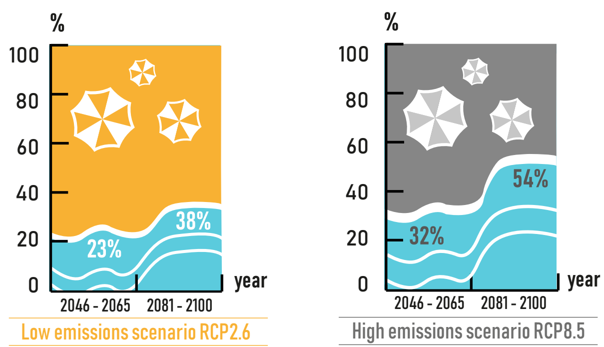


Figure 4.2. Beach reduction% (scaling approximation).

Source: SOCLIMPACT Deliverable Report - D4.4d. Report on the evolution of beaches.

4.2.1.2. Seagrass evolution

Seagrasses are the main habitat for coastal marine ecosystems. They provide different services like sediment retention (and thus, clearer waters), coastal protection (in front of marine storms), shelter for marine organisms, etc. Therefore, the state of the seagrasses is a convenient proxy for the state of coastal environment. That is, large well-preserved extensions of seagrasses lead to a better coastal marine environment, which in turn is more resilient in front of hazards. Our results suggest that no seagrass losses are expected for the Posidonia located in the coasts of Corsica (see **Figure 4.3**).

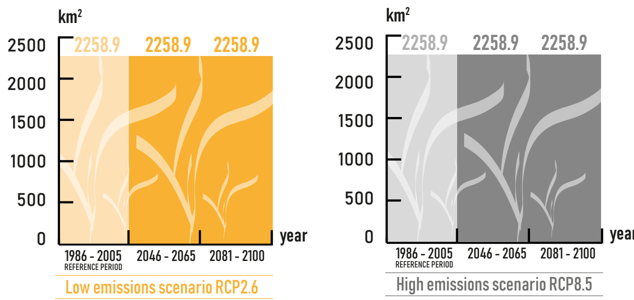


Figure 4.3. Seagrass evolution.

Source: SOCLIMPACT Deliverable Report - D4.4e. Report on estimated seagrass density.

4.2.1.3. Length of the window of opportunity for vector-borne diseases

Vector Suitability Index for Aedes Albopictus (Asian Tiger Mosquito)

Climate change can influence the transmission of vector-borne diseases (VBDs) through altering the habitat suitability of insect vectors. This is mainly controlled by increases of ambient air temperature and changes in the hydrological cycle. Thus, we explore if potential changes to meteorological conditions can affect the distribution of the Asian tiger mosquito (Aedes albopictus). Asian tiger mosquito is native to the tropical and subtropical areas of Southeast Asia; however, in the past few decades, this species has spread to many countries through the international transport of goods and increased travel (Scholte and Schaffner 2007). It is of great epidemiological importance since it can transmit viral pathogens and infectious agents that cause chikungunya, dengue fever, yellow fever and various encephalitides (Proestos *et al,* 2015).

The multi-criteria decision support vector distribution model of Proestos *et al.* (2015) has been employed to estimate the regional habitat suitability maps. This is based on extending previous work on the environmental/climatic factors affecting the life cycle of the Asian tiger mosquito (Waldock *et al,* 2013;

Proestos *et al.*, 2015). The mosquito habitat suitability model combines seven meteorological indices based on field observations, extensive literature review and expert knowledge.

Corsica is another example of suitable habitat for the Asian tiger mosquito. According to the European Centre of Disease Prevention and Control, populations of the mosquito have already been reported. The ensemble mean of EURO-CORDEX simulations suggest slight increases of the suitability for both 21st century time slices under scenario RCP2.6 and for the mid-century under scenario RCP8.5 (see **Figure 4.4**).

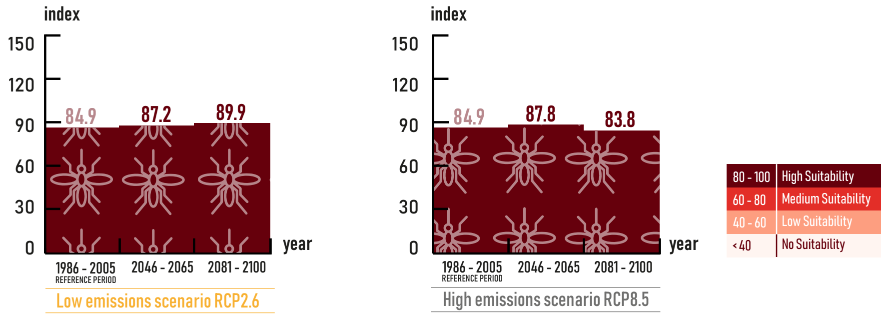


Figure 4.4. Habitat Suitability Index (HSI). 80-100: High Suitability; 60-80: Medium Suitability; 40-60: Low Suitability; <40 No Suitability.
Source: SOCLIMPACT Deliverable Report - 4.3. Atlases of newly developed indexes and indicators.

4.2.1.4. Fire Weather Index (FWI)

The FWI system provides numerical non-dimensional ratings of relative fire potential for a generalized fuel type (mature pine stands) based solely on weather observations. FWI is part of the Canadian Forest Fire Danger Rating System established in Canada since 1971 (van Wagner, 1987). Furthermore, since 2007, FWI has been adopted at the EU level and used in a harmonized way throughout Europe by the European Forest Fire Information System (EFFIS) of the Copernicus Emergency Management Service (since 2015).

It is selected for exploring the mechanisms of fire danger change for the islands of interest, as it has been proved to adequately perform for several locations, including the Mediterranean basin. The index was calculated for the fire season (defined from May to October) over the Mediterranean for all models, scenarios and periods.

For Corsica, N = 75 grid cells were retained from the models domain. In the following figure, the ensemble mean and the uncertainty is presented for all periods and RPCs. It seems that under RCP2.6, the index slightly increases at the middle of the century, while it returns to present levels towards the end of the century. On the other hand, under RCP8.5, there is an increased fire danger that exceeds 30% at the end of the century.

The fire danger for Corse is quite low and the majority of the island is characterized by very low fire danger, with few areas exhibiting medium danger. Though by the end of the century, areas with medium fire danger increase substantially.

Regarding uncertainty, the coastal areas of the islands present higher values of standard deviation, indicating that there are larger differences among models at the areas of the island with higher maritime influence (see respective maps) (see **Figure 4.5**).

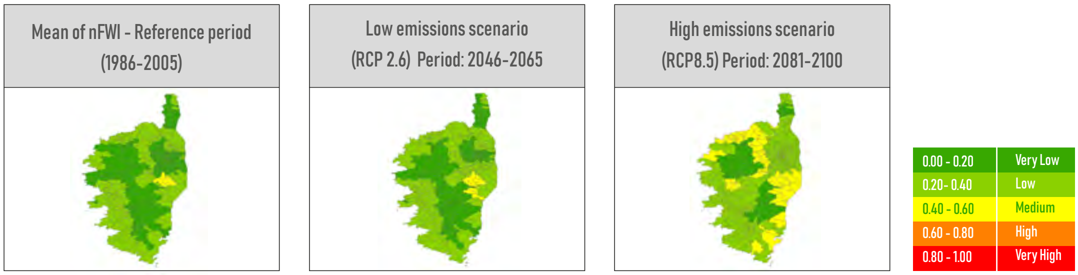
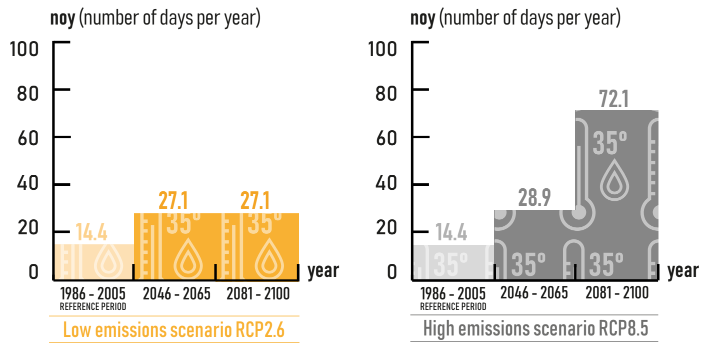


Figure 4.5. Fire Weather Index (EURO-CORDEX) with the color associated to the class of risk (Mediterranean study).
Source: SOCLIMPACT Deliverable Report - D4.4c. Report on potential fire behaviour and exposure.

4.2.1.5. Humidex

For the assessment of climate hazard on heat related impacts of climate change on human health, the humidity index (Humidex) (Masterton and Richardson, 1979) has been used. Humidex value is an equivalent temperature, which express the temperature perceived by people (the one that the human body would feel), given the actual air temperature and relative humidity. As a more representative indicator for the assessment of inhabitants' and tourists' hazard on heat related climate change impacts, the Number of Days with Humidex greater than 35 °C was selected. From the above classification, a day with Humidex above 35 °C describes conditions from discomfort to imminent danger for humans. For Corsica, N = 75 grid cells were retained from the models domain. In the following figure, the ensemble mean and the uncertainty is presented for all periods and RPCs (see **Figure 4.6**).



HUMIDITY INDEX-DISCOMFORT LEVEL	
<29°C	comfortable
30-34°C	some discomfort
35-39°C	discomfort; avoid intense exertion
40-45°C	great discomfort; avoid exertion
46-53°C	significant danger; avoid any activity
>54°C	imminent danger; heart stroke.

Figure 4.6. Number of days per year with Humidex > 35° C (Euro-CORDEX).

Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed indexes and indicator.

4.2.2. Aquaculture

Temperature changes in seawater trigger physical impacts; increased harmful algal blooms, decreased oxygen level, increase in diseases and parasites, changes in ranges of suitable species, increased growth rate, increased food conversion ratio and more extended growing season. Furthermore, all these impacts lead to socio-economic implications among them, changes in production levels and an increase in fouling and pests. The objective of the current analysis is to identify and quantify the variations (future climate scenarios with respect to present climate) in the number and in the duration of events characterized by a Sea Surface Temperature (SST) exceeding a given threshold. The SST thresholds have been identified according to the farming and feeding necessities of several marine species, particularly relevant for the aquaculture sector in the Mediterranean Sea (MS) (see **Figure 4.7**).

	Longest event (days) >20 degrees Mussels & clams	Longest event (days) >24 degrees Sea bream/Tuna	Longest event (days) >25 degrees Sea bass
Historic (1986-2005)	121 days	29.5 days	17.5 days
RCP 8.5 - mid century	144 days	91.5 days	42 days
RCP 8.5 - end century (2081-2100)	173.5 days	95.5 days	75 days

Species	Threshold (°C)
European seabass, Dicentrarchus labrax	25
Gilthead seabream, Sparus aurata	24
Amberjack, Seriola dumerili	23
Atlantic Bluefin tuna, Thunnus thynnus	23
Japanese clam, Ruditapes decussatus	21
Blue mussel, Mytilus edulis	21
Manila clam, Rudtape philippinarum	20
Mediterranean mussel, Mytilus galloprovinciales	20

Figure 4.7. Number of days per year exceeding a given threshold.

Source: SOCLIMPACT Deliverable Report - 4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

4.2.3. Energy

A series of indicators related to renewable energy productivity is presented. The productivity and variability of these renewable energy sources will depend on climate. The possibility of reduced productivity due to climate change poses a risk to the energy generation, if it is based on these renewable energy sources, as well as a possible increase in the frequency and duration of solar and wind energy.

4.2.3.1. Cooling Degree Days (CDD)

The Cooling Degree Days (CDD) index gives the number of degrees and the number of days that the outside air temperature at a specific location is higher than a specified base temperature, providing the severity of the heat in a specific time period taking into consideration outdoor temperature and average room (see **Figure 4.8**).

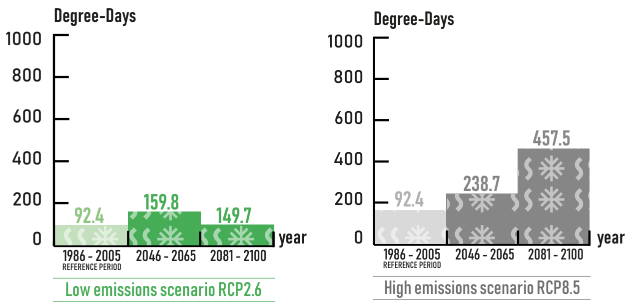


Figure 4.8. Cooling Degree Days. Ensemble mean of EURO-CORDEX simulations.

Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed hazard indexes and indicators with Appendices.

4.2.3.2. Available water: Standardized Precipitation Index

This index is used as an indication of water availability. Mild changes are projected under RCP2.6, while under the business-as-usual scenario the whole island is expected to be severely affected by meteorological droughts (see **Figure 4.9**).

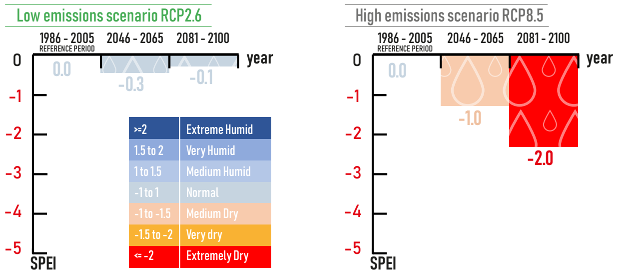


Figure 4.9. Ensemble mean values of the Standardized Precipitation Evaporation Index (SPEI) averaged.

Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed hazard indexes and indicators with Appendices.

4.2.4. Maritime Transport

Sea Level Rise (SLR) is one of the major threats linked to climate change. It would induce permanent flooding of coastal areas with a profound impact on society, economy and environment. Moreover, an increase in the mean sea level would result in a larger impact of coastal storms with the consequent increase of risk. The results are presented in terms of mean sea level rise. For Corsica, the SLR ranges from 21.31 cm (RCP2.6) to 58.41 cm (RCP8.5) at the end of the century (see **Figure 4.10**).

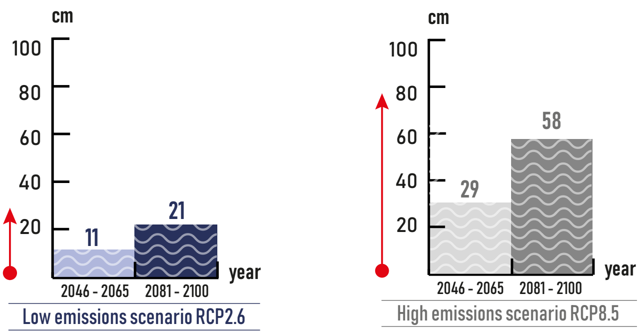


Figure 4.10. Mean sea level rise (in cm) with respect to the reference period (1986-2005). Ensemble mean of CMIP 5 simulations and scaling approximation for RCP2.6 and 8.5.

Source: SOCLIMPACT Deliverable Report - D4.4b. Report on storm surge levels.

4.2.4.1. Storm surge extremes

Storm surge events, characterized by positive extreme sea levels and mechanically forced by atmospheric pressure and wind, are the main responsible for coastal flooding, especially when combined with high tides.

To date, the only ensemble populated with enough number of members to compute meaningful statistics on climate projections is the one produced for the Mediterranean by Lionello *et al.* (2017). This ensemble consists on 6 simulations run with the HYPSE model at 1/4° of spatial resolution and forced by the high-resolution wind fields from the MedCORDEX ensemble, which in turn is nested into CMIP5 global simulations. The simulations are run for the period 1950-2100, thus covering the historical period as well as the whole 21st century. Complementary, the ensemble includes three hindcast simulations that are used to establish present reference levels. For Corsica, the results show a very low or even non-existent decrease except for RCP8.5 at the end of the century (-9%) (see **Figure 4.11**).

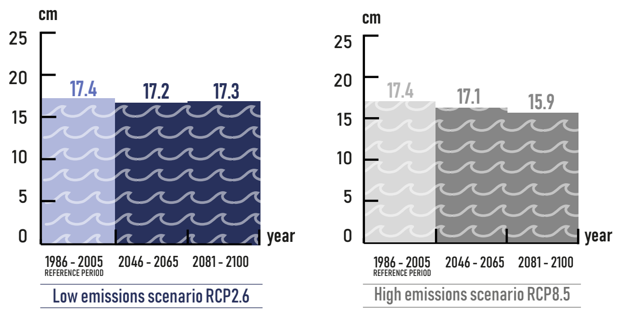


Figure 4.11. 99th percentile of atmospherically forced sea level (in cm) averaged for the hindcast period, the near future (2046-2065) and the far future (2081-2100) under scenarios RCP2.6 (with scaling approximation) and RCP8.5 and (relative change in %).

Source: SOCLIMPACT Deliverable Report - D4.4b. Report on storm surge levels.

4.2.4.2. Wind extremes

The wind extremity index NWIX98 is defined as the number of days per year exceeding the 98th percentile of mean daily wind speed. This number decreases in the far future under RCP8.5 (- 10.8%). The 98th percentile of daily wind speed, WIX98 decreases under RCP2.6. and RCP8.5 with a more significant magnitude for RCP2.6 (see **Figure 4.12**).

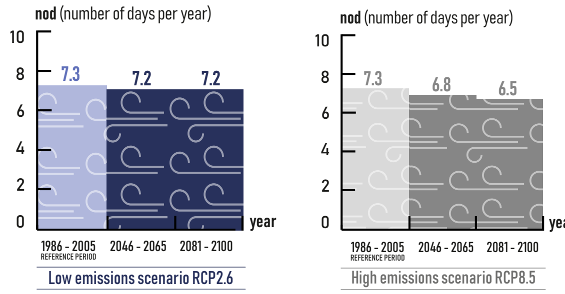


Figure 4.12. Wind Extremity Index (NWIX98). Ensemble mean of the EURO-CORDEX simulations.

Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed indexes and indicator.

4.3. Risk Assessment

4.3.1. Tourism

4.3.1.1. Loss of attractiveness due to increased danger of forest fires in touristic areas

For the reference period (1986-2005), the overall risk of forest fires is low for Corsica. It is maintained low in the near future (2046-2065) for both RCPs and even for RCP2.6 in the distant future (2081-2100). However, for RCP8.5 in the distant future, it moves to an overall medium risk of forest fires. This is due to its medium exposure score (having the highest score for forest covered areas) and primarily by its high vulnerability score, having the highest value in flammability index and a very low adaptive capacity (see **Figure 4.13** and **Figure 4.14**).

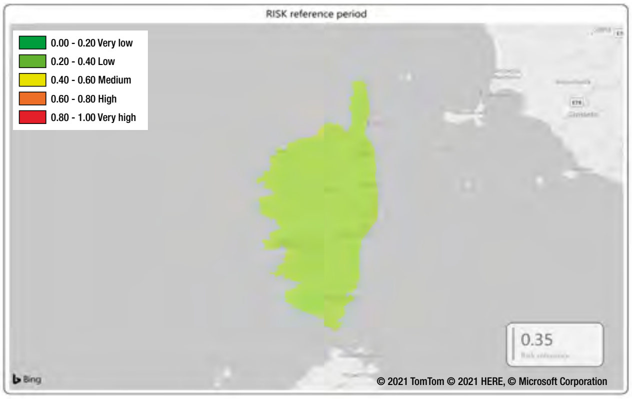


Figure 4.13. Risk score for the reference period.

Source: SOCLIMPACT Deliverable Report - D4.5. Comprehensive approach for policy makers.

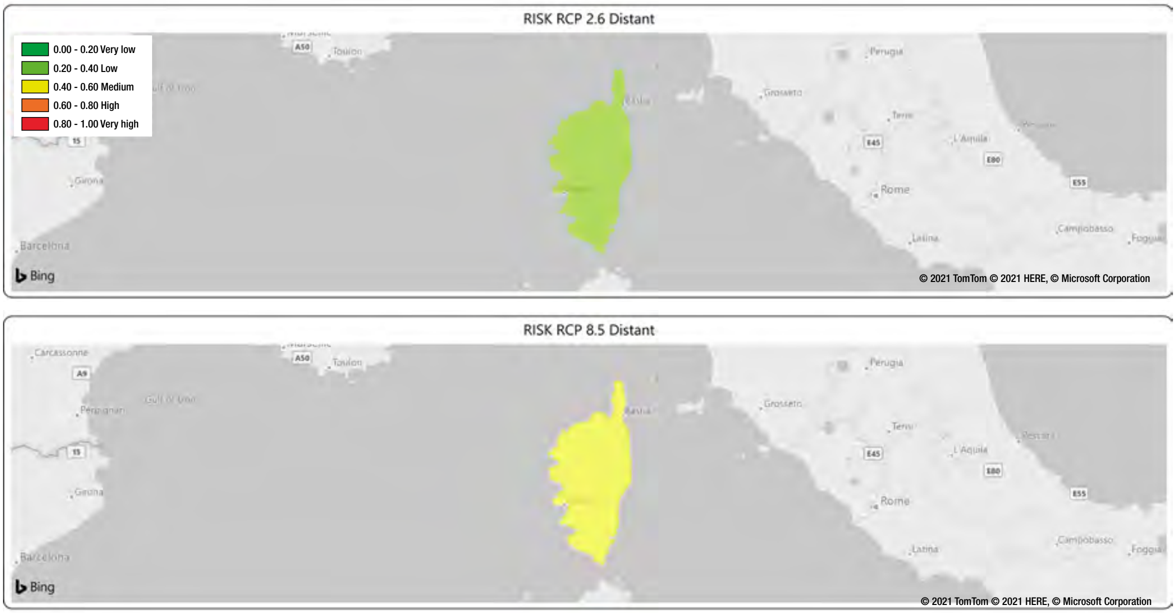


Figure 4.14. Risk score at the end in the distant future (2081-2100) under RCP2.6 (Ambitious Mitigation Policies) and RCP8.5 (Business as usual).

Source: SOCLIMPACT Deliverable Report - D4.5. Comprehensive approach for policy makers.

4.3.2. Aquaculture

4.3.2.1. Risk of increased fragility of aquaculture activity due to extreme weather events

Results for the hazard induced by mean wave motion appear to classify most Mediterranean offshore farm locations as semi-exposed sites (unlike those in the Atlantic, which are offshore). The probability of occurrence of extreme events that might prove unendurable for infrastructures moderately lowers the cumulative hazard. Results for Corsica exhibit increased uncertainty, clearly deriving from the extreme event component (see **Table 4.1**).

4.3.3. Maritime Transport

The maritime transport sector in the island of Corsica is found to be less susceptible to climate change, as our Impact Chain operationalization indicates the lowest risk values among all investigated islands (risk value of 0.22 for present conditions). This is related mostly to low exposure indicators. Under pathway RCP2.6, this value will be slightly reduced because the negative effect of increasing meteorological hazards is counterbalanced by an increase

Table 4.1. Risk results for impact chain "Extreme Weather Events" for the Mediterranean Islands.

Risk	Best-case scenario					Worst-case scenario				
	Reference period	Mid century		End century		Reference period	Mid century		End century	
	Hist.	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	Hist.	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Corsica	0.19	0.19	0.19	0.20	0.21	0.25	0.25	0.26	0.28	0.26
Cyprus	0.23	0.23	0.23	0.23	0.22	0.23	0.23	0.23	0.23	0.22
Malta	0.26	0.26	0.26	0.26	0.26	0.42	0.45	0.56	0.45	0.36
Sardinia	0.30	0.32	0.32	0.28	0.31	0.33	0.33	0.34	0.33	0.33
Sicily	0.20	0.20	0.20	0.20	0.20	0.30	0.34	0.33	0.33	0.26

in the adaptive capacity as the percentage of renewables is expected to increase in this low-emission pathway. Under scenario RCP8.5, the risk is expected to slightly increase by mid-21st century and reach a value of 0.273 by 2100. Read more about the risk indicator computation (normalization of sub-component indicators) on Appendices (see **Table 4.3**).

Table 4.2. Summary of present and future risk of isolation due to maritime transport disruption for each island and scenario based on the Impact Chain operationalization.

Risk value per island	Historical reference	RCP2.6 MID	RCP2.6 END	RCP8.5 MID	RCP8.5 END
Cyprus	0.241	0.210	0.218	0.258	0.292
Crete	0.229	0.208	0.201	0.257	0.282
Malta	0.376	0.347	0.335	0.395	0.414
Corsica	0.220	0.194	0.194	0.243	0.273
Canary Islands	0.336	0.292	0.250	0.346	0.341
Balearic Islands	0.326	0.281	0.264	0.331	0.344

Categorization:

0.00 – 0.20 Very low	0.20 – 0.40 Low	0.40 – 0.60 Medium	0.60 – 0.80 High	0.80 – 1.00 Very high

Source: SOCLIMPACT Deliverable Report 4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

4.4. Economic Impacts on the Blue Economy Sectors

4.4.1. Tourism (Non-Market Analysis)

In order to understand the effect of climate change on tourists' behavior, a representative sample of 2538 European citizens have been interviewed in their countries of origin. Through online surveys, tourists were asked how climate change impacts can affect their travelling decisions and the islands' destination choice (see **Figure 4.15**).

The technique of discrete choice experiments (DCEs) was implemented. This technique has been widely applied to the evaluation of tourists' preferences both in natural areas and other tourism contexts (Eymann and Ronning, 1997). It involves asking tourists to choose between alternative profiles or sets of attributes of the tourist destinations. The principal advantage of this method is that it allows researchers to investigate the preferences of various attributes of the tourist product simultaneously.

DCEs consist of several choice sets, each containing a set of mutually exclusive hypothetical alternatives between which respondents are asked to choose their preferred one. Alternatives are defined by a set of attributes, each attribute taking one or more levels. Individuals' choices imply implicit trade-offs between the levels of the attributes in the different alternatives included in a choice set. In particular, he will pick the one providing the highest utility, which depends on the

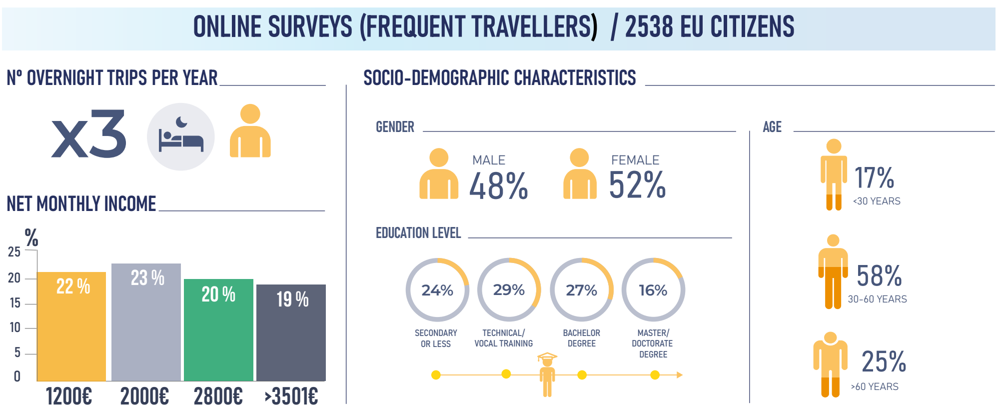


Figure 4.15. Socio-demographic profile of respondents.

Source: SOCLIMPACT Deliverable Report - D5.5. Report on market and non-market costs of Climate Change and benefits of climate actions for Europe.

attribute levels of the alternatives. Socio-economic characteristics of the individual may influence this decision. The resulting choices are finally analyzed to estimate the contribution that each attribute and level add to the overall utility of individuals. Moreover, when the cost or price is included as an attribute, marginal utility estimates can easily be converted into willingness-to-pay (WTP) estimates for changes in the attribute levels and, by combining different attribute changes, welfare measures may be obtained.

As a result of data analysis, a ranking of islands image was obtained, according to the opinion and the image that tourists have of each island under analysis. Besides, the percentage of tourists that would not visit any European island posed to climate change impacts was obtained, which alert on the potential decrease in tourism arrivals for these islands. Finally, the choice model allows to measure the changes in the willingness to pay of tourists for visiting these EU islands, which alert on how these impacts would affect tourism expenditure in the EU islands posed to climate change. The results are useful to evaluate the priorities in terms of risks management and responsiveness, from the tourism management perspective (see **Figure 4.16**).

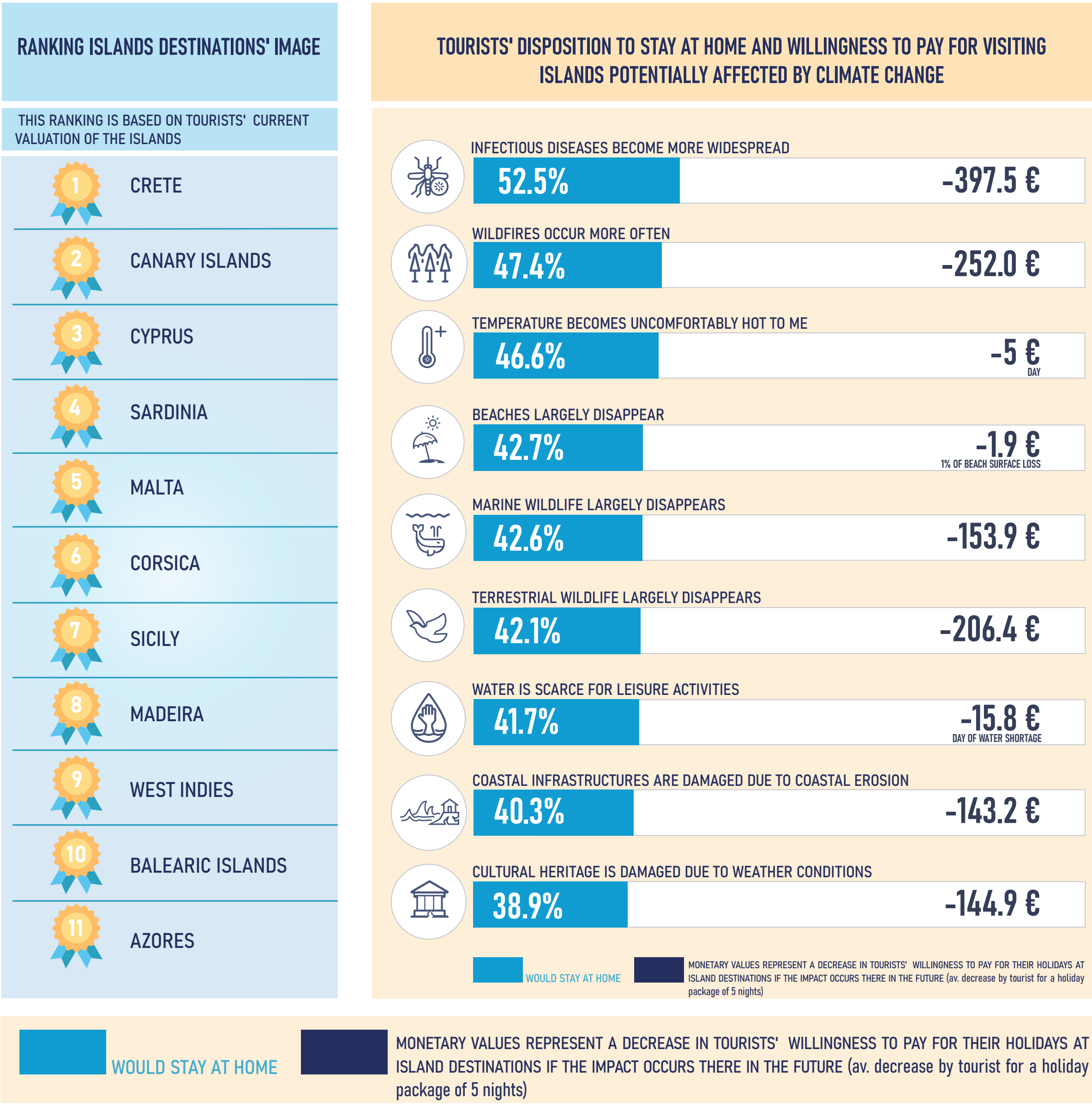


Figure 4.16. Tourists' preferences for islands destinations and tourists' behavioural response to climate change risks.

Source: SOCLIMPACT Deliverable Report - D5.5. Report on market and non-market costs of Climate Change and benefits of climate actions for Europe.

The impact of increased temperatures and heat waves on hotels' prices and revenues

In order to assess how the variation in temperature impacts on the tourism sector through changes in tourism demand our research question was: "How do increasing temperatures (and heat waves) impact prices and, more in general, expenditure of tourists?" Arguably, when temperatures grow, tourists adjust their behaviour: they might switch destination, or they might stay longer or shorter depending on their attitudes and preferences. In turn, all these changes modify the market equilibrium, pushing tourism companies to adjust their prices to re-establish the equilibrium between demand and supply. The change in demand and the change in price determine the change in tourism expenditure which is, from the destination's perspective, tourism revenue.

We monitored current weather conditions posted on several weather forecast providers and daily prices posted on Booking.com by hotels. We then estimated the link between daily temperature and daily price, controlling for all the other factors affecting prices. We finally applied these estimates to the increase in the number of days with excessive temperature projected for the future in two scenarios (RCP2.6 and RCP8.5) and in two time horizons (near future, about 2050 and distant future, about 2100).

Among the different indicators linked to thermal stress, we focus on two: the number of days in which the temperature is above the 98th percentile and the number of days in which the perceived temperature is above 35 °C. Although the impact for both indices was computed, in this document we only report the second one (named Humidex) because it is the most intuitive and because human thermal stress is more related to the absolute value of the temperature than its deviation from some pre-determined distribution. We assumed that thermal stress appears when the perceived temperature grows above 35 °C.

As thermal stress is delimited in the summer months, and this is when the great majority of tourists arrive in these islands, the whole analysis has been carried out in six months only: from May to October included. In other words, we assume that there is no thermal stress (and hence, no impact on tourism) in the rest of the year.

Initially, three islands were investigated: Corsica, Sardinia, and Sicily, given the massive amount of potential data. We focused the analysis in three specific areas, represented in the map below: the south-east area of Corsica (between Porto Vecchio and Boniface); the north-east area of Sardinia (Costa Smeralda) and the south-east area of Sicily (the coastal area of Catania and Siracusa provinces). Arguably, these are among the most important coastal tourism areas of these islands. Overall, 60 hotels (for a total of about 240,000 observations) were monitored in Corsica; 150 hotels (for a total of about 620,000 observations) were monitored in Sardinia; 129 hotels were monitored in Sicily (for a total of about 726,000 observations) over the period 1 May 2019 – 31 October 2019 (see **Figure 4.17**).

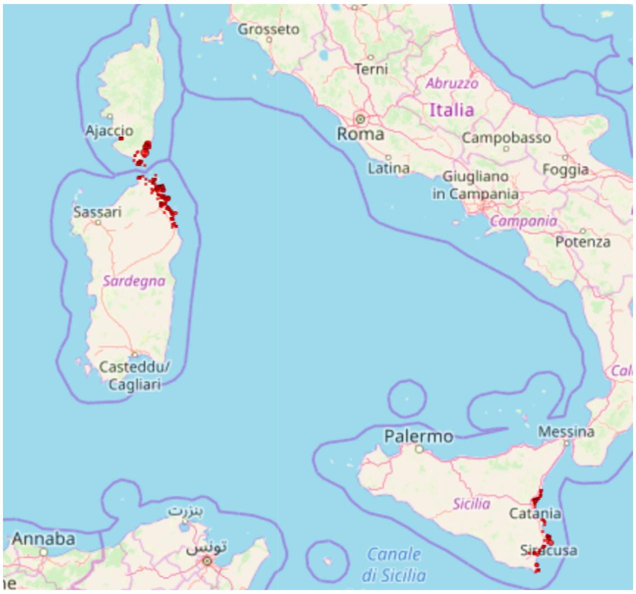


Figure 4.17. Map of the region.

Source: SOCLIMPACT Deliverable Report - D5.3. Data Mining from Big Data Analysis

To date, 7.89% (column 1 of the table below) of "summer" days (days in the period between 1 May and 31 October) have a Humidex higher than 35 °C in the area under investigation (Bonifacio and Porto Vecchio). In absolute terms, this is about 14 days.

In the future, this share (column 3) will almost double to 14.85% in RCP2.6, double (to 15.84%) in RCP8.5 near, and increase of four-fold (to 39.51%, about 71 days) in RCP8.5, distant. Consequently, demand for holidays in Corsica will increase, and the new equilibrium shows an increase in the average price posted by hotels in the destination (column 4) and an increase in overnight stays (column 5, this is estimated using the past correlation between average prices and occupancy rates in hotels, data provided by STR). The joint impact of price and demand will lead to an increase in hotels revenues (last column of the table) and, assuming that the change in revenues spreads to the other tourism products in a similar way, an increase in tourism revenues for the whole destination will be recorded. Hence, the estimation reported in the last column of the table below can be interpreted as the percentage increase in tourism revenues for the island (see **Table 4.3**).

Table 4.3. Estimation of increase in average price and revenues for Corsica.

Actual share of days in which Humidex > 35 degrees	Future scenario considered	Days in the corresponding scenario in which Humidex > 35 degrees	Increase in the average price	Increase in the tourism overnight stays	Increase in tourism revenues
7.89%	RCP 2.6 near	14.85%	2.6%	0.5%	3.2%
	RCP 2.6 far	14.85%	2.6%	0.5%	3.2%
	RCP 8.5 near	15.84%	3.0%	0.6%	3.6%
	RCP 8.5 far	39.51%	12.0%	2.4%	14.7%

Source: SOCLIMPACT Deliverable Report - D5.3. Data Mining from Big Data Analysis.

According to these findings, the average increase in temperature, which is correlated to a growing thermal stress for tourists, brings an economic advantage to tourism destinations. This is only an apparent contradiction with previous findings. This study does not neglect the fact that if islands are too hot, tourists will choose to move to other (cooler) destinations, that theoretically exist. In this study, the underlying assumption is instead that growing temperatures are a global issue, thereby, not modifying the relative position of a destination. Then, the increase in tourism (and tourism revenues) stem from the fact that, when the temperature is too hot, people would prefer to move to coastal areas (where the climatic conditions are more bearable) than staying inland or in cities. Future trends will also facilitate this pressure of tourism demand (think about the spreading of smart working activities where, in principle, the worker can relocate wherever he/she wants).

4.4.2. Aquaculture

The effects of increased sea surface temperature on aquaculture production were calculated using a lethal temperature threshold by species, and considering the production share of the region. Four different future scenarios shown by IPCC estimations (RCP2.6 and RCP8.5 near and distant) were analysed, which correspond to four water temperature increases in the region with respect to the reference period.

To do this, we assume three main species cultured in this region: seabream, seabass and mussels and a model of production function, calculating the monthly biomass production which depends on the monthly water temperature. Results are presented on a yearly base (mean values). In order to facilitate the interpretation of the results, we present the value of production of the last year available, for which we calculate the new values under the different climate change scenarios.

The production levels (tons) will decrease only if surface temperature increase more than 1 °C above the reference value. In both cases, the average annual increase is in levels below 21 °C, the threshold of thermal stress for mussels, the most sensitive species (see **Figure 4.18**).

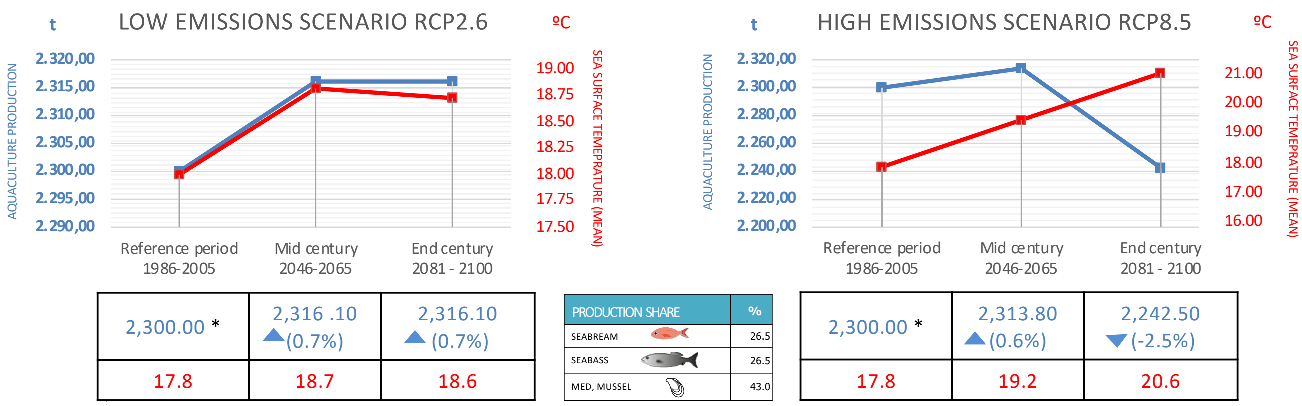


Figure 4.18. Estimations of changes in aquaculture production (tons), due to increased sea surface temperature.

Source: SOCLIMPACT Deliverable Report D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

4.4.3. Energy

Climate change may impose welfare reductions to the European islands' societies by affecting thermal comfort. Cooling Degree Days (CDD) are a measure of how much (in degrees), and for how long (in days), outdoor air temperature is higher than 21 °C. The CDD is used as a measure of the energy needed to cool buildings. The increase in CDD and the energy demand (GWh/year) for cooling are estimated for the islands under different scenarios of global climate change.

Under the high emissions scenario, it is expected that the CDD increase to 457 CDD. Under this situation, the increase in cooling energy demand is expected to be 753 % (see **Figure 4.19**).

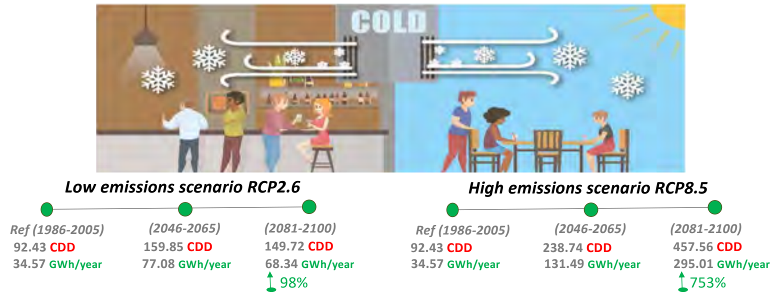


Figure 4.19. Estimations of increased energy demand for cooling in Corsica under different scenarios of climate change until 2100.

Source: SOCLIMPACT Deliverable Report D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

4.4.4. Maritime Transport

For maritime transport, it has been estimated the impact of Sea Level Rise on ports' operability costs of the island. The costs have been calculated with reference to 1 meter; this is, the investment needed to increase the infrastructures' height by 1 meter. There is not necessarily a strict correspondence between the SLR and the required elevation of port infrastructures, which also depends on the coastal hydrodynamic and the shape of dikes of each port. By experts' recommendation, we have assumed that 1 meter increase in port height is required to cope with the SLR under RCP8.5 scenario of emissions. Extrapolation for other RCP scenarios is then conducted based on proportionality.

The starting point was the identification of the principal ports in the island (economic relevance). Second, the analysis of the different port areas (exterior, ramps, oil, etc.), and their uses. Third, the elevation costs were estimated per each area and port separately (considering 1 meter elevation). Thus, the costs of 1 meter elevation presented are the sum of all areas and ports analysed. Estimations consider that all ports areas of the entire area should be elevated at the same time. In other words, the economic values can be interpreted as the depreciation (amortization) costs of the investment needed to increase all porsts' infrastructures' in the island for a 125 years time horizon. No discount rate has been applied.

As expected, the rising of sea levels will affect the sector, so new investment will be needed to keep ports' operability. Under the high emissions scenario, it is expected that these costs could increase 1.14 million euros per year until the end of the century (see **Figure 4.20**).

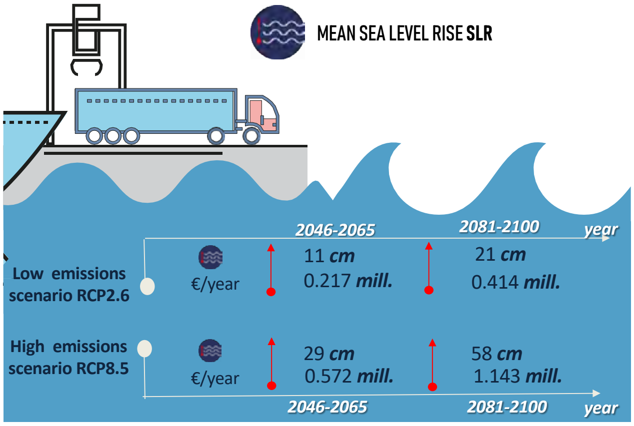


Figure 4.20. Increased costs for maintaining ports' operability in Corsica under different scenarios of SLR caused by climate change until 2100.

Source: SOCLIMPACT Deliverable Report D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

4.5. Towards Climate Resiliency

With regards to its policies, the Corsica government has drafted the following plans and strategies.

National scale

- Climate-Impact Knowledge GICC 1999.
- National Strategy 2007.

- National Consultation.
- PNACC (National Plan for Adaptation to Climate Change) 2011-2015.
- 2015 PNACC Assessment.
- Proposal Development 2016-2017.
- 2019 PNACC (second).

Island scale

- Climate Change Adaptation Plan - Corsica Basin (2018).
- The Plan for Development and Sustainable Development of Corsica (PADDUC).
- The Regional Plan of Climate of Air and Energy (SRCAE).
- Multiannual Energy Program (PPE).
- MedCOP.
- Territorial Climate-Air-Energy Plans (PCAET).
- The Regional Plan for Air Quality.
- National Strategy for Integrated Coastline Management.

In general, stakeholders in the island identify three main limitations:

- Key land use, spatial planning, urban planning and maritime spatial planning policies do not consider the impacts of climate change.
- Initiatives disconnected from the metropolitan territory sometimes.
- There is a lack of reliable statistics and information related to exposure and vulnerability of the island to climate change. These are important components that worsen climate risks and respond to human interventions (more pressure). In addition, detailed climate change vulnerability assessment is still not very well understood. Therefore, the island's adaptation focus should be, first, the development of reliable information systems for the periodic monitoring of these components.

4.5.1. Policy Recommendations

A stakeholders consultation process was carried out in the island, aiming to propose, analyse and rank alternative adaptation measures for the island. The profile of the individuals participating in these focal groups involved policy and decision-makers, practitioners, non-governmental and civil society organisations, science experts, private sector, business operators and sector regulators at island level.

The main aim of these meetings was:

1. Identify and present the characterized packages of adaptation and risk management options for the island.
2. Develop detailed integrated adaptation pathways in three timeframes: Short term (up to 2030), Mid-century (up to 2050) and End-century (up to 2100).
3. Evaluate and rank adaptation options for 2 blue economy sectors in the island (aquaculture and tourism).

To this aim, stakeholders utilized five evaluation criteria to rank the proposed measures:

- Cost efficiency: Ability to efficiently address current or future climate hazards/risks in the most economical way.
- Environmental protection: Ability to protect the environment, now and in the future.
- Mitigation win-wins and trade-offs: Current ability to meet (win-win) or not (trade-off) the island / archipelagos mitigation objectives.
- Technical applicability: Current ability to technically implement the measure in the island.
- Social acceptability: Current social acceptability of the measure in the island.

Four scenarios of intervention were analysed, called Adaptation Policy Trajectories which are different visions of future policy adaptation choices:

- APT A Minimum Intervention - Low investment, low commitment to policy change.
- APT B Economic Capacity Expansion - High investment, low commitment to policy change.
- APT C Efficiency Enhancement - Medium investment, medium commitment to policy change.
- APT D System Restructuring - High investment, high commitment to policy change.

It was assumed that adapting to climate change may range from minimal to high cost, and from requiring a small or incremental change to a significant transformation from the *status quo*. However, not all APT scenarios were considered in all islands, especially when their stakeholders had a clear vision on the types of measures with greatest viability. Therefore, the final set of proposed adaptation measures are framed in the islands' socio-economic and political context, have a sectoral perspective, and respond to the islands' future scenarios of climate change. At the same time, the involvement of regional stakeholders in policy design allows them to engage in the effective implementation of climate actions on their island.

In Appendices from K to N, a brief explanation of each adaptation option can be found, classified by type or class: Vulnerability Reduction, Disaster Risk Reduction, Social-Ecological Resilience, and Local Knowledge. The latest group refers to very specific measures proposed by stakeholders in each island to ratify the needs.

4.5.1.1. Tourism

In APTA, actions that are less resource intensive are preferred by stakeholders to actions stronger in investment. Respondents explained that raising awareness among tourists on detrimental beach erosion caused by removing seagrass banks is a cost intensive and high impact measure. In APTB, economic instruments are preferred over incentives to relocate activities, which is in line with the economic orientation of the scenario. In APTC, circular economy is by far preferred to tourist awareness raising. Circular economy is an important challenge with large political interest in Corsica.

From APT A to D, and especially in APTD, the diversification of tourism is chosen earlier and more often than awareness raising. This illustrates the good understanding of APTs by respondents. Since Corsica is a low-risk area for water scarcity, the adaptation solutions linked to this risk are less chosen (see **Table 4.4**).

Table 4.4. Proposed adaptation options for tourism in Corsica.

<table>
<tr><td rowspan="6">APT A – Pathway
—
Minimum Intervention
low investment, low commitment to policy change
—
This policy trajectory assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td colspan="3">Public awareness programmes</td></tr>
<tr><td colspan="3">Coastal protection structures</td></tr>
<tr><td colspan="3">Health care delivery systems</td></tr>
<tr><td colspan="3">Post-disaster recovery funds</td></tr>
<tr><td colspan="3">Monitoring, modelling and forecasting systems</td></tr>
<tr><td rowspan="7">APT B – Pathway
—
Economic Capacity Expansion
high investment, low commitment to policy change
—
This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td colspan="2">Economic Policy Instruments (EPIs)</td><td>Financial incentives to retreat from high-risk areas</td></tr>
<tr><td colspan="2">Public awareness programmes</td><td>Activity and product diversification</td></tr>
<tr><td colspan="3">Beach nourishment</td></tr>
<tr><td colspan="3">Coastal protection structures</td></tr>
<tr><td colspan="3">Monitoring, modelling and forecasting systems</td></tr>
<tr><td colspan="3">Dune restoration and rehabilitation</td></tr>
<tr><td rowspan="10">APT C – Pathway
—
Efficiency Enhancement
medium investment, medium commitment to policy change
—
This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td colspan="2">Public awareness programmes</td><td>Activity and product diversification</td></tr>
<tr><td>Tourist awareness campaigns</td><td colspan="2">Local circular economy</td></tr>
<tr><td colspan="3">Water restrictions, consumption cuts and grey-water recycling</td></tr>
<tr><td colspan="3">Coastal protection structures</td></tr>
<tr><td colspan="2">Using water to cope with heat waves</td><td>Mainstreaming Disaster Risk Management</td></tr>
<tr><td colspan="3">Monitoring, modelling and forecasting systems</td></tr>
<tr><td colspan="3">Dune restoration and rehabilitation</td></tr>
<tr><td colspan="2">Adaptive management of natural habitats</td><td>Ocean pools</td></tr>
<tr><td rowspan="7">APT D – Pathway
—
System Restructuring
high investment, high commitment to policy change
—
This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td>Economic Policy Instruments (EPIs)</td><td colspan="2">Financial incentives to retreat from high-risk areas</td></tr>
<tr><td>Public awareness programmes</td><td colspan="2">Activity and product diversification</td></tr>
<tr><td colspan="3">Water restrictions, consumption cuts and grey-water recycling</td></tr>
<tr><td>Drought and water conservation plans</td><td colspan="2">Coastal protection structures</td></tr>
<tr><td colspan="3">Pre-disaster early recovery planning</td></tr>
<tr><td colspan="3">Monitoring, modelling and forecasting systems</td></tr>
</table>

Vulnerability Reduction *Disaster Risk Reduction* *Socio-Ecological Resilience* *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

4.5.1.2. Aquaculture

According to the results, there is a clear hierarchy of stakeholders preferences, the multitrophic integrated aquaculture is often chosen, as well as local consumption, species selection and disease prevention, while short cycle aquaculture or fish food production are more rarely chosen.

When choices and APT are considered, we see that:

- Local consumption of aquaculture products is preferred to local environmental concerns.
- Integrated multitrophic aquaculture is preferred by far to short cycle aquaculture.
- Submersible cages are preferred to indoor aquaculture.
- Species selection are preferred to fish food improvement.

In APTA, short term soft measures are preferred more often and at long term, while in APT B, C, and even more on D, actions including some restructuring of relocation are chosen, which seems consistent with the pathway's rationale (see **Table 4.5**).

Table 4.5. Proposed adaptation options for aquaculture in Corsica.

APT	Short-term (up to 2030)	Mid-century (up to 2050)	End-of-century (up to 2100)
APT A – Pathway — **Minimum Intervention** low investment, low commitment to policy change — This policy trajectory assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts	Awareness campaigns for behavioural change		Efficient feed management
	Climate proof aquaculture activities		Risk-based zoning and site selection
	Mainstreaming Disaster Risk Management		Contingency for emergency management, early harvest and/or relocation
	Recovery Post-disaster plans		
	Species selection		
APT B – Pathway — **Economic Capacity Expansion** high investment, low commitment to policy change — This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy	**Short-term (up to 2030)**	**Mid-century (up to 2050)**	**End-of-century (up to 2100)**
	Financial schemes, insurance and loans		Tax benefits and subsidies
	Efficient feed management	Awareness campaigns for behavioural change	
	Submersible cages		Recirculation Aquaculture Systems (RAS)
	Climate proof aquaculture activities		Risk-based zoning and site selection
	Species selection		
	Best Management Practices	Selective breeding	
APT C – Pathway — **Efficiency Enhancement** medium investment, medium commitment to policy change — This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system	**Short-term (up to 2030)**	**Mid-century (up to 2050)**	**End-of-century (up to 2100)**
	Awareness campaigns for behavioural change		Efficient feed management
	Addressing consumer and environmental concerns at the local level	Promote cooperation to local consumption	
	Integrated multi-trophic aquaculture		
	Climate proof aquaculture activities	Risk-based zoning and site selection	
	Environmental monitoring Early Warning Systems (EWS)	Disease prevention methods	
	Species selection		
	Best Management Practices		
	Create educational visits	Promote aquaculture cuisine	
APT D – Pathway — **System Restructuring** high investment, high commitment to policy change — This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems	**Short-term (up to 2030)**	**Mid-century (up to 2050)**	**End-of-century (up to 2100)**
	Financial schemes, insurance and loans	Tax benefits and subsidies	
	Awareness campaigns for behavioural change	Efficient feed management	
	Integrated multi-trophic aquaculture		
	Climate proof aquaculture activities	Risk-based zoning and site selection	
	Recovery Post-disaster funds		
	Feed production	Species selection	

Vulnerability Reduction · *Disaster Risk Reduction* · *Socio-Ecological Resilience* · *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

Chapter

5

Crete (Greece)

SOCLIMPACT

This project has received funding from
the European Union's Horizon 2020 research
and innovation programme under
Grant Agreement No 776661

CONTENTS

Crete at a Glance

Crete is the 5th largest island in the Mediterranean and the largest and most populous of Greek islands. The island's population was estimated to 635,000 in 2019. The total area of Crete is 8,336 sq. km (6.3 % of the total area of the Greek territory). It has a remarkable coastline of more than 1000 km.

The island is extremely mountainous with three main mountain ranges, Psiloritis (Idi) (2456 m), Lefka Ori (2454 m) and Dikti (Lassithi Mountains) (2148 m), which cross it from the west to east.

Crete is one of the most popular holiday destinations in Greece, accounting for 24 % of Greek tourism receipts. Although Crete is producing a wide range of high-quality agricultural products, being one of the most self-sufficient regions of Greece, its main income comes from tourism and services.

The Blue Economy Sectors

- **Aquaculture**

  The fisheries sector, along with aquaculture, is considered important for the economy of Crete, despite its small contribution to GDP, as it contributes to maintaining the economic and social cohesion of large areas of the island. The main type of aquaculture that is carried out in Crete is marine aquaculture and a few small freshwater farms in the inland. There is also a freshwater aquaculture unit of spiroulina production farm. The main marine species commercially cultured is the gilthead seabream (Sparus aurata) and European seabass (Dicentrachus labrax).

- **Maritime Transport**

  In Crete, due to the large coastline, the port system is very extensive, consisting of a large number of ports and port facilities of different sizes, while its contribution to the economy of the island is particularly important. Maritime transport is key for the region's development but is also part of the growing economic activities. In Crete there are a number of port facilities , which mainly concern 2 ports of international importance (Port of Heraklion and port of Souda), 1 of national importance (port of Rethymno) and 2 of major importance (port of Agios Nikolaos and port of Sitia), along with a large number (about 60) fishing shelters and marinas.

- **Energy**

  The energy industry in the Region of Crete has as its main pillars the three steam power stations (HPP): Chania, Linoperama and Atherinolakkos, while the Local Production Station (GSP) of Gavdos is in operation, with an installed nominal power of 430 kW. Electricity is produced mainly by imported fuel oil (78 %), while renewable sources hold a moderate share in total power generation. The share of renewable sources in total electricity production reaches 22 % in 2018 (solar and wind), with the largest part being attributed to solar power generation. The electrical interconnection of Crete with Attica and the Peloponnese, via a submarine cable is in the process of implementation.

- **Tourism**

  Crete is an island with incomprehensible diversity and contrasts that attracts many tourists every year. Tourism is the most dynamically developing sector and the demand gave incentives for important investments in hotel units, resulting in the qualitative and quantitative upgrading of hotel infrastructures. An important competitive advantage of the tourist branch is the high percentage of high standard hotel infrastructures. Crete has 30.31 % of the total of 5-star beds in Greece and 24.57 % of 4-star beds, respectively. It welcomes approximately 15 % of all international tourism to Greece. Tourism-related revenues account for almost 35 % of the regional GDP.

5.1. Current Climate and Risks

The climate of Crete is generally described as mild Mediterranean. The atmosphere can be quite humid, depending on the proximity to the sea, while winter is fairly mild. The precipitation in Crete is characterized by spatial and temporal variations increasing towards the western and north parts of the island. Western Crete (Chania province) receives more rain compared to the Eastern part of Crete. The island is mountainous with mean elevation of 482 m ranging from sea level to 2450 m (Psiloritis, Lefka Ori). Snowfall is common on the mountains between November and May, but rare in the low-lying areas.

During the Cretan summer, average temperatures reach the high 20s-low 30s Celsius with maxima touching the upper 30s-mid 40s. More sunny days and higher temperatures prevail across the south coast, including the Messara valley and Asterousia mountains, driven mainly by the prevailing North African climatic zone. In general, a basic characteristic of the local climate are large deviations from place to place.

Extreme events, such as meteorological droughts, hydrological droughts, extreme low temperatures and extreme precipitation events are becoming more intense and frequent due to climate change. In recent years, major weather events have become more common in Crete.

In 29/5/2013 multiple wildfires in Regional Unit of Chania caused estimated disaster cost €1.915.545. Strong southerly winds blowing in the area were hampering fire-fighting efforts, while the entire fire brigade of the region had been mobilised in response to multiple fires that broke out in the region.

Crete has experienced torrential rainfall and flooding for two times during February 2019. Hit by two storms, Crete has seen extreme levels of heavy rain during February. Some areas recorded around 400 mm of rain between 12 and 17 February. Floods of 12-13/2/2019 & 24-25/2/2019 caused 4 deaths and one person missing. First estimation of disaster cost was €100 million for R.U. of Chania and in total €263 million for the Island (see **Figure 5.1**).

CURRENT CLIMATE-RELATED RISKS

- Coastal flood High
- Landslide High
- Wildfire High

SIGNIFICANT CLIMATE EVENTS

- Heatwave (summer 2017)
- Drought (2018)
- Rainfall (2008, 2017)
- Floods (2013)

CLIMATE CHARACTERISTICS (35.34°N 25.14°E, 1m asl)

Average temperature and precipitation

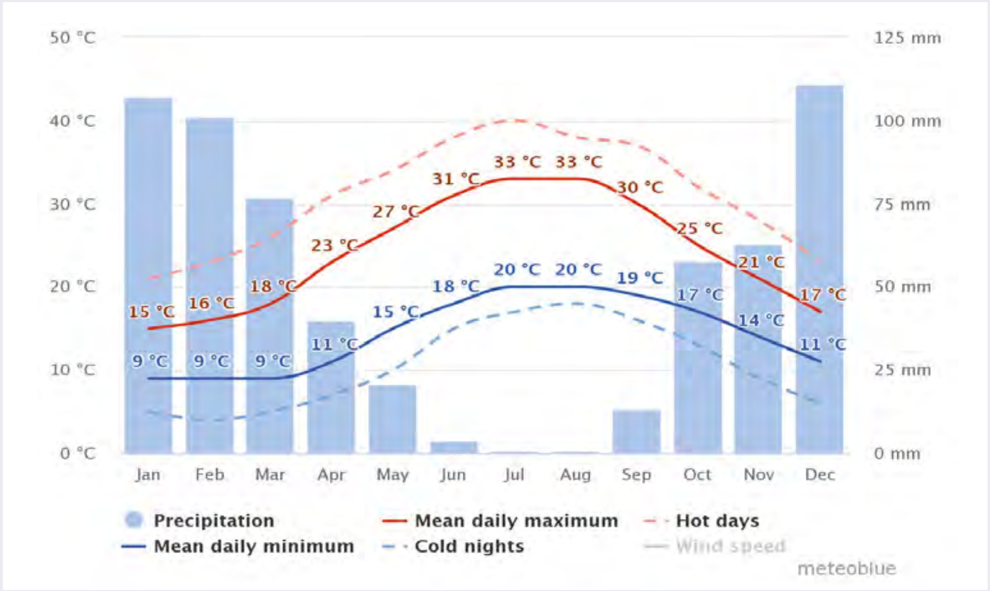
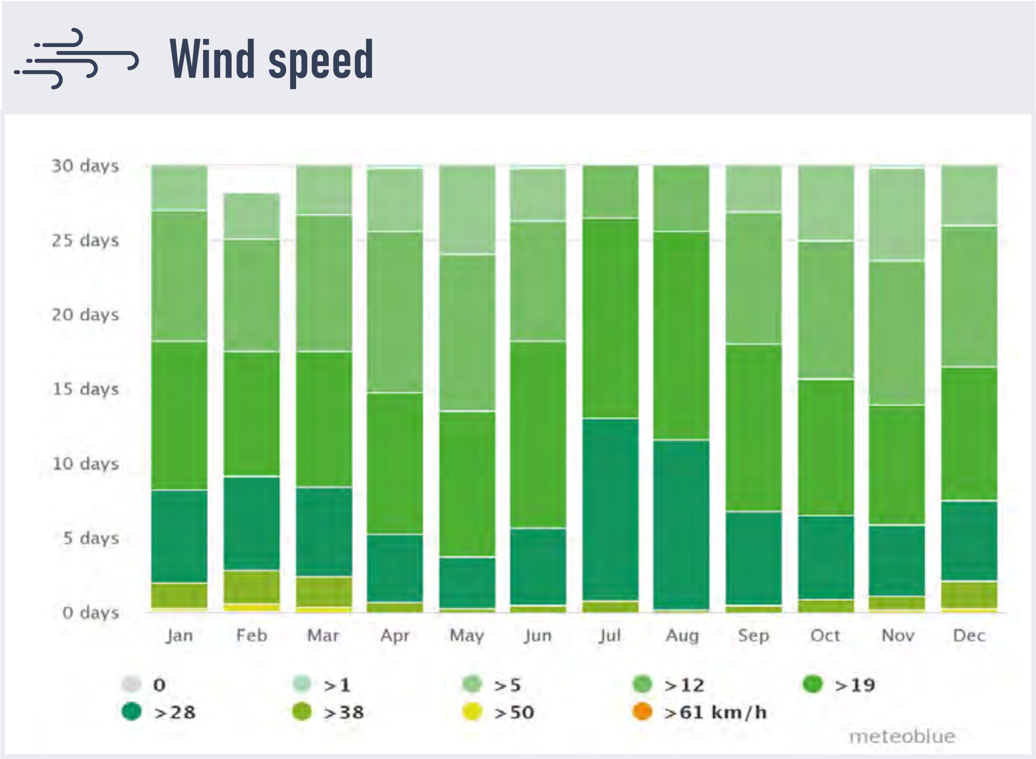


Figure 5.1. Climate factsheet.

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System). **(Continued on the next page)**



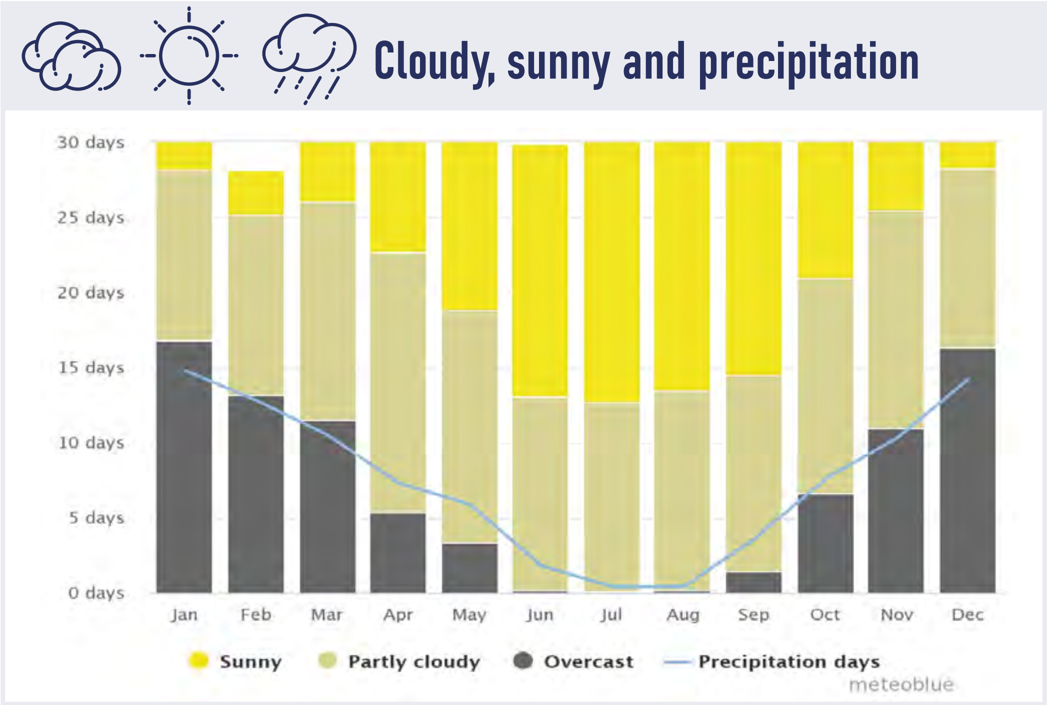


Figure 5.1 (Cont.). Climate factsheet.

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System). **(Continued on the next page)**

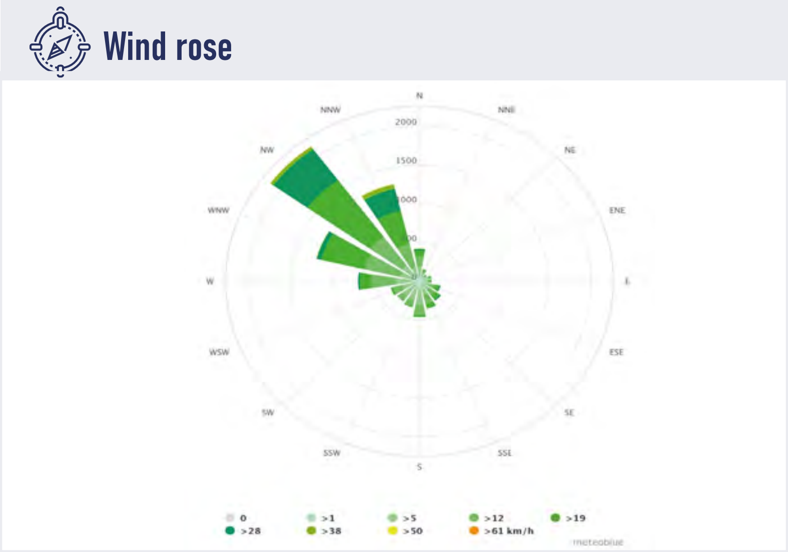


Figure 5.1 (Cont.). Climate factsheet.

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System).

5.2. Macroeconomic Projections

Based on the projections, Crete will grow with an average annual rate of 1.6% throughout the 2015-2100 period and with 2.1% throughout the 2015-20150 period. In the short-run, the main driver of growth are investments while, in the long-run, it is the increase in private consumption expenditures which supports this growth (Table 5.1). Trade surpluses, the largest part of which is attributed to intra-national trade, are expected to diminish over time and to follow a more balanced path. Still, Crete remains a net exporter in 2100. In the short term, investments grow with a high pace, counterbalancing the lack of investments during the economic crisis, while presenting a stable growth rate throughout the 2025-2050. We assume that the share of public consumption slightly decreases until 2100; nevertheless, per capita public consumption expenditures increase over the time period under consideration (see **Figure 5.2** and **Table 5.1**).

5.2.1. The Sectoral Projections

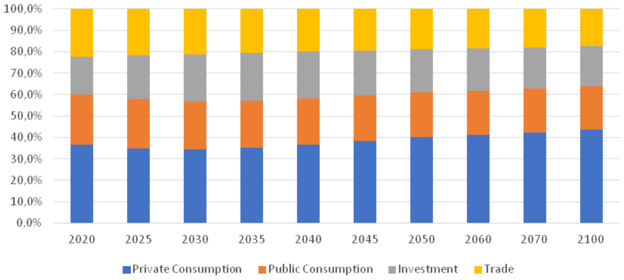


Figure 5.2. Macroeconomic components as a% share of GDP for Crete in 2015-2100.

Source: SOCLIMPACT Deliverable Report - D6.2. Modelling socioeconomic impacts for EU islands.

Table 5.1. Crete GDP and GDP components yearly growth rates in 2020-2100.

	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
GDP	2.3%	2.6%	2.3%	2.1%	2.1%	1.9%	1.7%	1.6%	1.5%	1.0%
Private consumption	1.8%	1.6%	2.0%	2.6%	2.9%	2.8%	2.7%	2.1%	2.1%	1.4%
Public consumption	1.9%	2.2%	1.9%	1.7%	1.7%	1.5%	1.3%	1.4%	1.3%	1.0%
Investments	5.3%	5.7%	3.6%	2.5%	1.6%	1.2%	0.7%	1.3%	1.0%	0.9%
Exports	1.7%	2.0%	2.0%	2.2%	2.1%	1.8%	1.7%	1.8%	1.7%	1.3%
Imports	1.8%	2.0%	2.1%	2.5%	2.3%	2.0%	2.0%	2.1%	1.9%	1.6%

Source: SOCLIMPACT Deliverable Report - D6.2. Modelling socioeconomic impacts for EU islands.

The Cretan economy remains a service-led economy throughout the 2015-2100 period with an increasing contribution of market, accommodation and food services. In 2015, non-market services were the second largest sector in the economy, but in 2100, it is projected that accommodation and food services will take their place mainly to the tourism led growth projected.

Blue growth sectors increase in importance throughout the 2015-2100 period. In particular, tourism grows from 22.9% as a share of GDP in 2015 to 26.1% in 2100[1]. While the water transport sector grows steadily, travel agency and related activities register a declining share in total value added as they grow with a lower rate than that of GDP (see **Figure 5.3**).

The most important Blue growth industry in Crete is tourism; tourism related expenditures are calculated to 22.9% of the regional GDP in 2015. This share is expected to reach 26.1% in the end of the projection period. Total employment of sectors associated with tourism increases by 18.1% over the projection period and increase should be largely attributed to tourism as most of their demand is non-domestic. For the rest of the Blue growth sectors, their contribution to GDP is expected to remain stable over the projection period: namely the share of aquaculture will continue to be around 0.1% and that of water transport services around 0.2% (see **Table 5.2**).

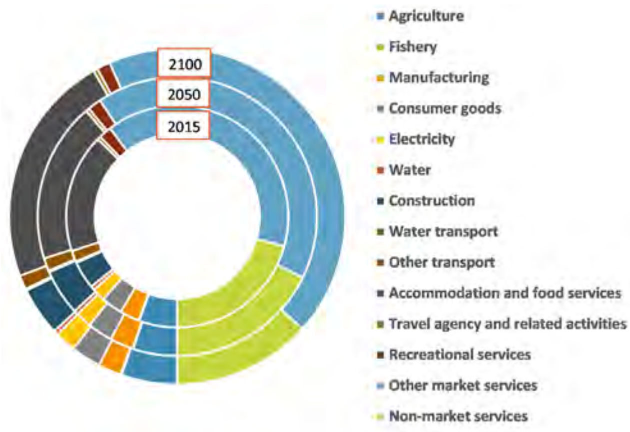


Figure 5.3. Sectoral value added as a% share to total GVA for Crete in 2015, 2050 and 2100.

Source: SOCLIMPACT project Deliverable Report - D6.2. Modelling socioeconomic impacts for EU islands.

Table 5.2. Sectoral contribution as a% share of total gross value added for Crete in 2015-2100.

GVA% shares	2015	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
Agriculture	5.6%	5.2%	4.9%	4.9%	4.9%	5.0%	5.0%	5.1%	5.3%	5.7%	5.4%
Fishery	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Manufacturing	2.9%	2.8%	2.9%	2.9%	2.8%	2.8%	2.8%	2.7%	2.6%	2.6%	2.3%
Consumer goods	3.1%	3.0%	2.9%	2.9%	2.9%	2.9%	2.9%	2.9%	2.9%	3.0%	2.9%
Electricity	1.9%	1.8%	1.8%	1.8%	1.8%	1.8%	1.8%	1.9%	1.9%	2.0%	2.1%
Water	0.6%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.4%
Construction	4.0%	4.5%	5.3%	5.6%	5.8%	5.7%	5.6%	5.3%	5.2%	5.1%	4.7%
Water transport	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Other transport	1.6%	1.6%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.4%
Accommodation and food services	17.3%	17.6%	17.7%	17.8%	18.0%	18.2%	18.3%	18.5%	19.0%	19.2%	22.5%
Travel agency and related activities	0.5%	0.5%	0.5%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
Recreational services	1.8%	1.8%	1.7%	1.7%	1.6%	1.6%	1.6%	1.6%	1.5%	1.5%	1.3%
Other market services	39.7%	39.9%	39.9%	40.1%	40.5%	40.9%	41.2%	41.5%	42.1%	42.6%	43.2%
Non-market services	20.7%	20.5%	20.1%	19.6%	19.0%	18.5%	18.2%	17.8%	16.8%	15.8%	13.4%

Source: SOCLIMPACT project Deliverable Report - D6.2. Modelling socioeconomic impacts for EU islands.

[1] The share of tourism in GDP is calculated via the tourism satellite account (TSA) matrices of 2015, assuming that the same shares that indicate the contribution of tourism to the productions of tourism-related sectors (such as the accommodation and food services, transport services, travel agency and related activities, cultural and recreational activities) remain throughout the 2015-2100 period. Please, SOCLIMPACT Deliverable Report D6.2 for the complete database of the estimated TSAs.

The largest share of exports is attributed to exports of services rather than goods. With respect to trade in goods, agricultural products are significant for the region's trade position. Their exports account for 9.3% of total regional exports, as well as the exports of consumer good's industries (mainly of food and beverages) which account for 7.7% of total Cretan exports. Nevertheless, their shares are expected to diminish over the projection period for two reasons: the first one being the small income elasticity for these product categories and the second one is that a largest part of the output of the industry will serve to satisfy domestic demand. With respect to the Blue growth sectors, accommodation services record the most significant increase as their export share is expected to reach approximately 37% of total regional exports (from around 30% in 2015) (see **Table 5.3**).

Table 5.3. Sectoral contribution as a% share of total gross value added for Azores in 2015-2100.

	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
Tourism	22.9%	22.7%	22.6%	22.4%	22.6%	22.7%	22.7%	22.8%	23.2%	23.5%

Source: SOCLIMPACT Deliverable Report D6.2. Modelling socioeconomic impacts for EU islands.

5.2.2. Employment

The service-led economic growth brings positive effects to the labor market with unemployment projected to fall from 24.3% in 2015 to more sustainable levels until 2050. The contribution of each sector to total employment depends on the labor intensity of the sector. The biggest employing sectors are the market, non-market services, accommodation and food services, as well as agriculture. Employment in agriculture is expected to decrease over the period examined mainly due to the adoption of more efficient cultivation methods and the automation of agricultural production. The construction sector records significant increase until the mid-century due to the foreseen investment projects and the higher investments associated with the tourism industry. Tourism is largest employer of the Blue growth sectors under analysis, particularly due to the high labor intensity of accommodation and food services. Water transport employs only a small share of total, and thus, it has the lowest contribution among the Blue Growth sectors (see **Figure 5.4** and **Table 5.4**).

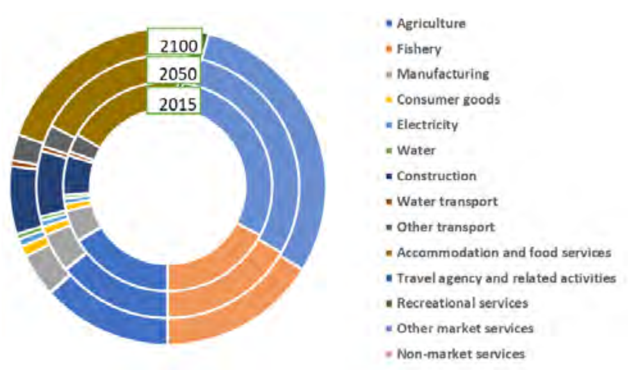


Figure 5.4. Sectoral employment as a% share of total for Crete in 2015, 2050, 2100.

Source: SOCLIMPACT project Deliverable Report - D6.2. Modelling socioeconomic impacts for EU islands.

5.3. Climate Change Outlook

Climate hazards indicators represent the entry point to understand the climate change exposure of the blue economy sectors. The indicators have been computed for two scenarios, RCP2.6 (low emission scenario) and RCP8.5 (high emission scenario) and for different horizon times namely: a reference period (1965-2005), mid-century (2046-2065) and end of century (2081-2100). Main source of climate projections (future climate) for Crete is EURO-CORDEX ensemble even if other model sources were applied when required, depending of available scales. Results are presented in form of maps, tables or graphs and only when the information shows an interesting outcome.

5.3.1. Tourism

5.3.1.1. Beach flooding and related losses

One of the consequences of an increase in the mean sea level will be the flooding of coastal areas. This includes sand beaches, which are the main asset for tourism activities in most of the European islands. Therefore, estimating the potential risk of beach loss due to climate change is of paramount importance for the economy of those islands.

Table 5.4. Unemployment rate for Crete in 2020-2100.

	2015	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
Unemployment rate	24.3%	20.1%	18.7%	17.1%	16.5%	14.3%	11.6%	9.9%	8.6%	8.6%	8.6%

Source: SOCLIMPACT Deliverable Report D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

The 95th percentile of the flood level averaged was selected as an indicator of interest. The values are presented as anomalies with respect to the present mean sea level at beach location (i.e., including the median contribution of runup). In all cases, an increase is expected being larger at the end of the century under scenario RCP8.5. The values in that scenario are 116.54 cm in Crete. Under mean conditions, we find that, at end of century, the total beach surface loss range from ~38% under scenario RCP2.6 to ~68% under scenario RCP8.5 (see **Figure 5.5**).

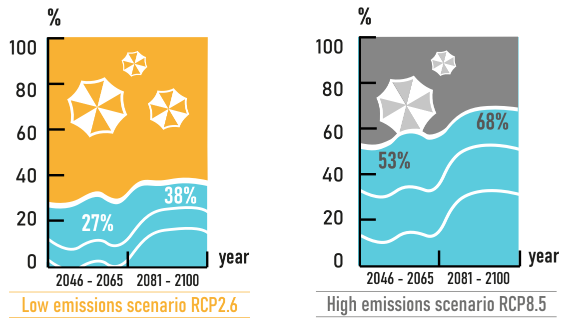


Figure 5.5. Beach reduction % (scaling approximation).
Source: SOCLIMPACT Deliverable Report - D4.4d. Report on the evolution of beaches.

5.3.1.2. Seagrass evolution

Seagrasses are the main habitat for coastal marine ecosystems. They provide different services like sediment retention (and thus, clearer waters), coastal protection (in front of marine storms), shelter for marine organisms, etc. Therefore, the state of the seagrasses is a convenient proxy for the state of coastal environment. That is, large well-preserved extensions of seagrasses lead to a better coastal marine environment, which in turn is more resilient in front of hazards. Our results suggest that no seagrass losses are expected for the Posidonia located in the coasts of Crete island (see **Figure 5.6**).

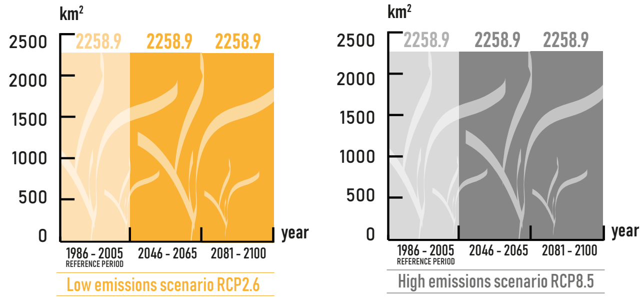


Figure 5.6. Seagrass evolution.
Source: SOCLIMPACT Deliverable Report - D4.4e. Report on estimated seagrass density.

5.3.1.3. Length of the window of opportunity for vector-borne diseases

Vector Suitability Index for Aedes Albopictus (Asian Tiger Mosquito)

Climate change can influence the transmission of vector-borne diseases (VBDs) through altering the habitat suitability of insect vectors. This is mainly controlled by increases of ambient air temperature and changes in the hydrological cycle. Thus, we explore if potential changes to meteorological conditions can affect the distribution of the Asian tiger mosquito (Aedes albopictus). Asian tiger mosquito is native to the tropical and subtropical areas of Southeast Asia; however, in the past few decades, this species has spread to many countries through the international transport of goods and increased travel (Scholte and Schaffner, 2007). It is of great epidemiological importance since it can transmit viral pathogens and infectious agents that cause chikungunya, dengue fever, yellow fever and various encephalitides (Proestos *et al.,* 2015) (see **Figure 5.7**).

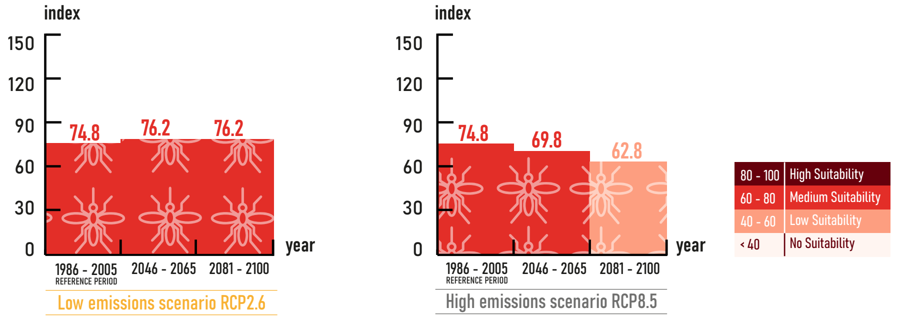


Figure 5.7. Habitat Suitability Index (HSI). [80-100: High Suitability; 60-80: Medium Suitability; 40-60: Low Suitability; <40 No Suitability].
Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed indexes and indicators.

The multi-criteria decision support vector distribution model of Proestos *et al.* (2015) has been employed to estimate the regional habitat suitability maps. This is based on extending previous work on the environmental/climatic factors affecting the life cycle of the Asian tiger mosquito (Waldock *et al.,* 2013; Proestos *et al.*, 2015). The mosquito habitat suitability model combines seven meteorological indices based on field observations, extensive literature review and expert knowledge.

For the Greek island of Crete, the environmental conditions are also favorable for the establishment of Aedes Albopictus. Future regional simulations under RCP2.6 suggest a small increase in the values of HSI. In agreement with the future trends for Cyprus, pathway RCP8.5 implies a decrease in the habitat suitability. This is more evident in the central inland regions and in the southwest parts of the island.

5.3.1.4. Fire Weather Index (FWI)

The FWI system provides numerical non-dimensional ratings of relative fire potential for a generalized fuel type (mature pine stands) based solely on weather observations. FWI is part of the Canadian Forest Fire Danger Rating System established in Canada since 1971 (van Wagner, 1987). Furthermore, since 2007, FWI has been adopted at the EU level and used in a harmonized way throughout Europe by the European Forest Fire Information System (EFFIS) of the Copernicus Emergency Management Service (since 2015).

It is selected for exploring the mechanisms of fire danger change for the islands of interest, as it has been proved to adequately perform for several locations, including the Mediterranean basin. The index was calculated for the fire season (defined from May to October) over the Mediterranean for all models, scenarios and periods.

For Crete, N = 78 grid cells were retained from the models' domain. In the following figure, the ensemble mean and the uncertainty are presented for all periods and RPCs.

The fire danger in Crete is among the highest in the Mediterranean. For the present climate, the most areas of the island pertain to the medium fire danger classification. It seems that, under RCP2.6, the index increases by almost 10% at the middle of the century, while this increase is halted towards the end of the century. On the other hand, under RCP8.5, the fire danger increases substantially, reaching a 30% increase at the end of the century, while there are areas in the central and southern parts of the island that cross over into very high fire danger.

Regarding uncertainty, we find that, under RCP2.6, the standard deviation decreased in most areas towards the end of the century, indicating the model projections for the FWI meet for this scenario, while the opposite is found for RCP8.5, where the uncertainty is higher at the end of the century (see **Figure 5.8**).

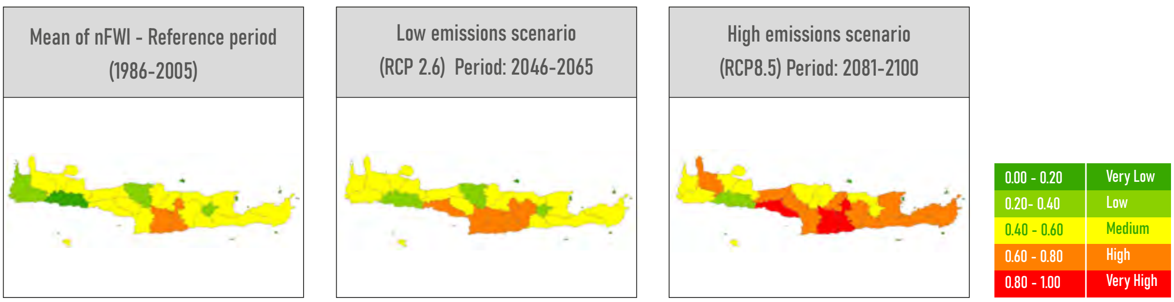
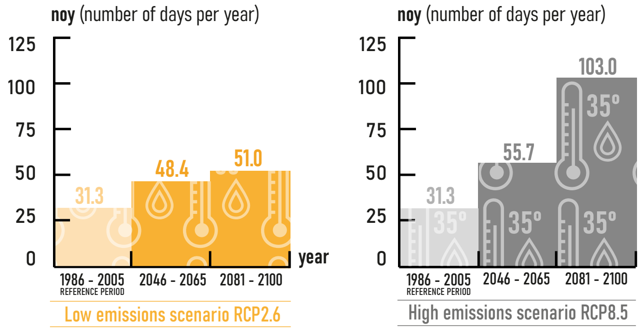


Figure 5.8. Fire Weather Index (EURO-CORDEX) with the color associated to the class of risk (Mediterranean study).
Source: SOCLIMPACT Deliverable Report - D4.4c. Report on potential fire behaviour and exposure.

5.3.1.5. Humidex

For the assessment of climate hazard on heat related impacts of climate change on human health, the humidity index (Humidex) (Masterton and Richardson, 1979) has been used. Humidex value is an equivalent temperature, which express the temperature perceived by people (the one that the human body would feel), given the actual air temperature and relative humidity. As a more representative indicator for the assessment of inhabitants' and tourists' hazard on heat related climate change impacts, the Number of Days with Humidex greater than 35 °C was selected. From the above classification, a day with Humidex above 35 °C describes conditions from discomfort to imminent danger for humans.

For Crete, N = 78 grid cells were retained from the models domain. In the following figure, the ensemble mean and the uncertainty are presented for all periods and RPCs. From one month in the present climate and 1.5 month in the mid-century for both scenarios, Crete will have 3.5 months with discomfort conditions by the end of the century under RCP8.5 (see **Figure 5.9**).



HUMIDITY	INDEX-DISCOMFORT LEVEL
<29°C	comfortable
30-34°C	some discomfort
35-39°C	discomfort; avoid intense exertion
40-45°C	great discomfort; avoid exertion
46-53°C	significant danger; avoid any activity
>54°C	imminent danger; heart stroke.

Figure 5.9. Number of days per year with Humidex > 35° C (Euro-CORDEX).

Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed indexes and indicator.

5.3.2. Energy

A series of indicators related to renewable energy productivity is presented. The productivity and variability of these renewable energy sources will depend on climate. The possibility of reduced productivity due to climate change poses a risk to the energy generation, if it is based on these renewable energy sources, as well as a possible increase in the frequency and duration of solar and wind energy.

5.3.2.1. Percentage of days when T > 98th percentile - T98p

The T98p is defined as the percentage of time where the mean daily temperature T is above the 98th percentile of mean daily temperature calculated for the reference period 1986-2005.

For Crete, N = 78 grid cells were retained from the models domain. The ensemble mean and the uncertainty are presented for all periods and RCPs. It is found that T98p is about 7 % during RCP2.6 towards mid-century and slightly decreases at the end of the century, while for RCP8.5 more than one fifth of the year will exhibit temperatures above the 98th percentile by the end of the century. The coastal grid cells, mainly in the north, are more affected by the temperatures increase compared to the inland grid cells (see **Figure 5.10**).

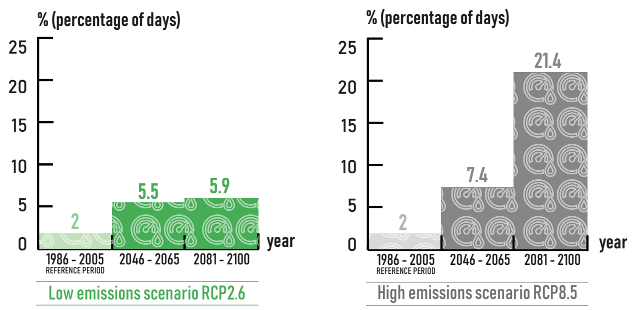


Figure 5.10. Percentage of days when T>98th percentile. Ensemble mean of EURO-CORDEX simulations.

Source: SOCLIMPACT Deliverable Report - D4.4a. Report on solar and wind energy.

5.3.2.2. Cooling Degree Days (CDD)

The Cooling Degree Days (CDD) index gives the number of degrees and number of days that the outside air temperature at a specific location is higher than a specified base temperature, providing the severity of the heat in a specific time period taking into consideration outdoor temperature and average room (see **Figure 5.11**).

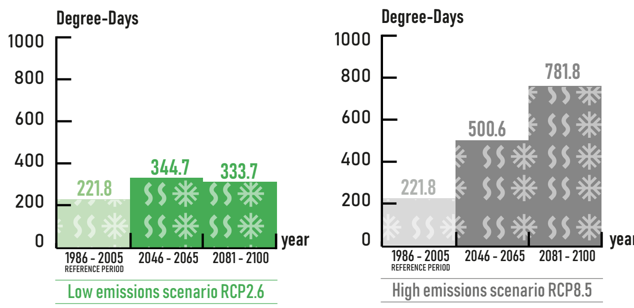


Figure 5.11. Cooling Degree Days. Ensemble mean of EURO-CORDEX simulations.

Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed hazard indexes and indicators with Appendices.

5.3.2.3. Available water: Standardized Precipitation Index

For Crete, only some regions of the north-east of the island are expected to be affected under RCP2.6 and exceed the "dry" conditions threshold. Under the business-as-usual

RCP8.5 forcing, parts of the island are expected to experience extreme dry conditions that will be evident even from the mid-21st century. Mild changes are projected under RCP2.6, while under the business-as-usual scenario the whole island is expected to be severely affected by meteorological droughts (see **Figure 5.12**).

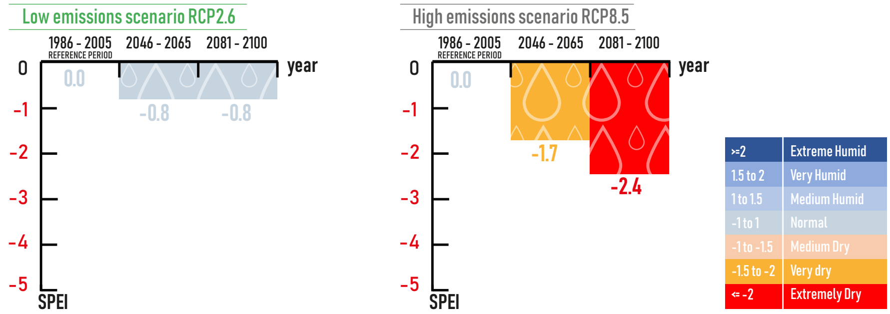


Figure 5.12. Ensemble mean values of the Standardized Precipitation Evaporation Index (SPEI) averaged.

Source: SOCLIMPACT Deliverable [Report - D4.3](). Atlases of newly developed hazard indexes and indicators with Appendices.

5.3.3. Maritime Transport

5.3.3.1. Sea Level Rise

Sea Level Rise (SLR) is one of the major threats linked to climate change. It would induce permanent flooding of coastal areas with a profound impact on society, economy and environment. Moreover, an increase in the mean sea level would result in a larger impact of coastal storms with the consequent increase of risk. The results are presented in terms of mean sea level rise. For Crete, the SLR ranges from 28.90 cm (RCP2.6) to 57.81 cm (RCP8.5) at the end of the century (see **Figure 5.13**).

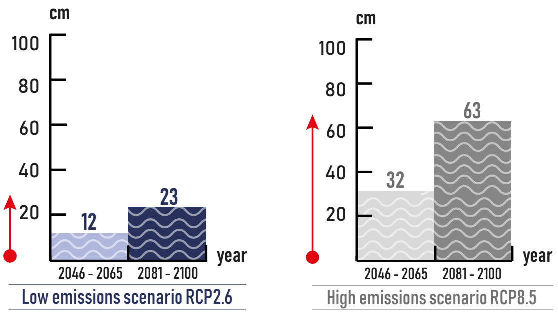


Figure 5.13. Mean sea level rise (in cm) with respect to the reference period (1986-2005). Own elaboration based on global and regional simulations.

Source: SOCLIMPACT Deliverable [Report - D4.4b](). Report on storm surge levels.

5.3.3.2. Storm surge extremes

Storm surge events, characterized by positive extreme sea levels and mechanically forced by atmospheric pressure and wind are the main responsible for coastal flooding, especially when combined with high tides.

To date, the only ensemble populated with enough number of members to compute meaningful statistics on climate projections is the one produced for the Mediterranean by Lionello *et al.* (2017). This ensemble consists on 6 simulations run with the HYPSE model at 1/4° of spatial resolution and forced by the high-resolution wind fields from the MedCORDEX ensemble, which in turn is nested into CMIP5 global simulations. The simulations are run for the period 1950-2100, thus covering the historical period as well as the whole 21st century. Complementary, the ensemble includes three hindcast simulations that are used to establish present reference levels. For Crete, the results show a very low or even non-existent decrease except for RCP8.5 at the end of the century (-13%) (see **Figure 5.14**).

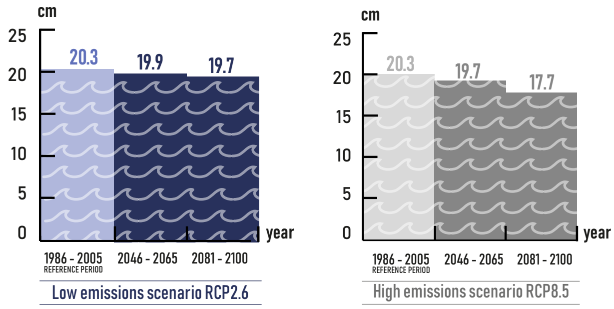


Figure 5.14. 99th percentile of atmospherically forced sea level (in cm) averaged for the hindcast period, the near future (2046-2065) and the far future (2081-2100) under scenarios RCP2.6 (with scaling approximation) and RCP8.5 and (relative change in %).

Source: SOCLIMPACT Deliverable [Report - D4.4b](). Report on storm surge levels.

5.3.3.3. Frequency of extreme high winds (Wind Extremity Index – NWIX98)

The wind extremity index NWIX98 is defined as the number of days per year exceeding the 98th percentile of mean daily wind speed. This number increases for both scenarios in both horizons. Like the NWIX98, the 98th percentile of daily wind speed, WIX98, decreases under RCP8.5 (see **Figure 5.15**).

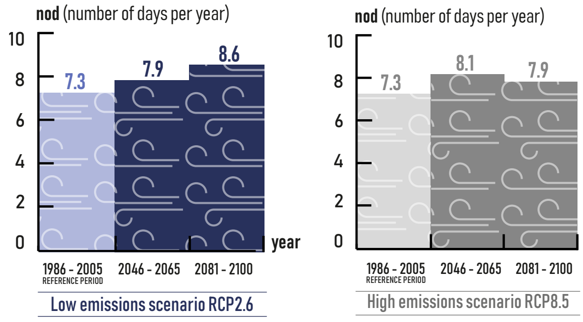


Figure 5.15. Wind Extremity Index (NWIX98). Ensemble mean of the EURO-CORDEX simulations.

Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed indexes and indicator.

5.3.3.4. Wave extremes (99th percentile of significant wave height averaged)

Marine storms can have a negative impact on maritime transport, coastal-based tourism and aquaculture, among other activities. To illustrate this impact, the 99th percentile of significant wave height averaged has been chosen. A decrease in the extreme wave height is found being larger under scenario RCP8.5 as illustrated in the following map along the south coast and an increase along the north coast (see **Figure 5.16**).

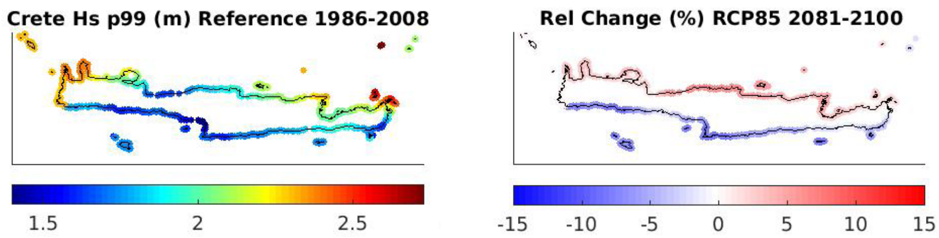


Figure 5.16. The 99th percentile of significant wave height averaged for the reference period and the relative change for the RCP8.5. Own elaboration based on global and regional simulations.

Source: SOCLIMPACT Deliverable Report - D4.4b. Report on storm surge levels.

5.4. Risk Assessment

5.4.1. Tourism

5.4.1.1. Loss of attractiveness due to increased danger of forest fires in touristic areas

For the reference period (1986-2005), the overall risk of forest fires is medium for Crete. It is maintained in the near future (2046-2065) for both RCPs, and even for RCP2.6 in the distant future (2081-2100). However, for RCP8.5 in the distant future it moves to an overall high risk of forest fires, becoming one of the regions with the highest risk together with Cyprus. This is mainly due to the predominance of the hazard component (fire danger), which is more prominent in eastern and south areas of the Mediterranean, and continues to worsen over time (very high fire danger score in the distant future) (see **Figure 5.17** and **Figure 5.18**).

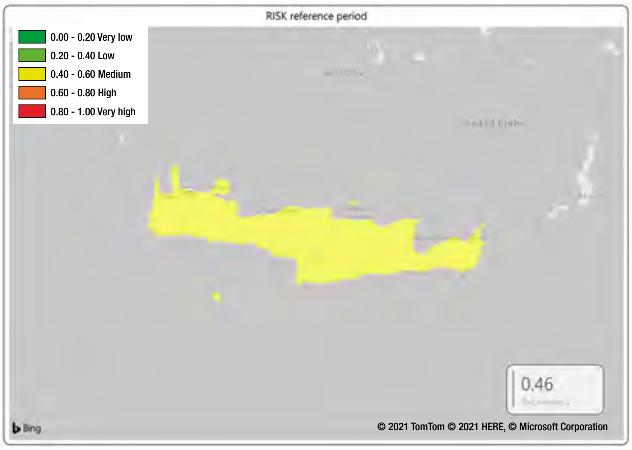


Figure 5.17. Risk score for the reference period.

Source: SOCLIMPACT Deliverable Report – D4.5. Comprehensive approach for policy makers.

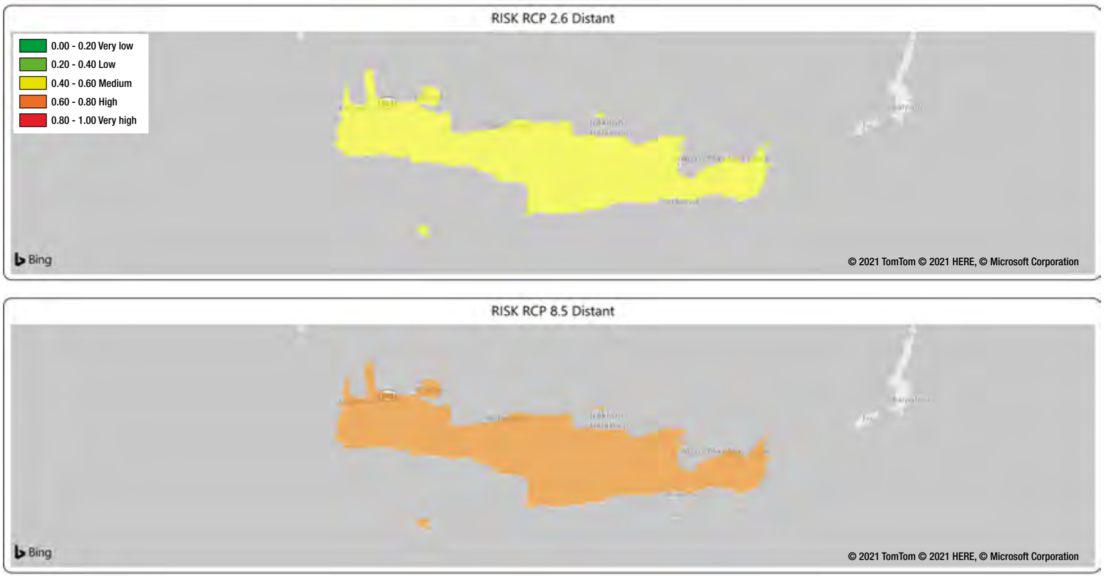


Figure 5.18. Risk score at the end in the distant future (2081-2100) under RCP2.6 (Ambitious Mitigation Policies) and RCP8.5 (Business as usual). *Source: SOCLIMPACT Deliverable Report – D4.5. Comprehensive approach for policy makers.*

5.4.2. Maritime Transport

For the largest Greek island during the historical reference period, the Impact Chain operationalization indicates similar conclusions as the case of Cyprus. The risk value is characterised as low (0.229) with more important contribution arriving from the factors of adaptive capacity. This is due to the low contribution of renewables and the relatively low number of harbour alternatives (e.g., airports) in the particular island. For RCP2.6, the risk of transport disruption is projected to slightly decrease for the middle and remain stable for the end of the 21st century. This is mainly due to a higher contribution of renewable energy. This higher contribution makes the island less dependent on the imported fossil fuel for energy production and, therefore, increases its capacity to adapt and be self-sustained. For the business-as-usual RCP8.5, our analysis indicates an increase for the end of the current century (risk value of 0.28). This increase can be attributed to the projected augmentation of meteorological hazards (mainly extreme winds and mean sea level rise). The fact that Crete is one of the islands where the level of exposure indicators (population, number of passengers and value of goods) is expected to strongly decrease, keeps future risk for transport disruption in relatively low levels (see **Table 5.5**).

Table 5.5. Summary of present and future risk of isolation due to maritime transport disruption for each island and scenario based on the Impact Chain operationalization.

Risk value per island	Historical reference	RCP2.6 MID	RCP2.6 END	RCP8.5 MID	RCP8.5 END
Cyprus	0.241	0.210	0.218	0.258	0.292
Crete	0.229	0.208	0.201	0.257	0.282
Malta	0.376	0.347	0.335	0.395	0.414
Corsica	0.220	0.194	0.194	0.243	0.273
Canary Islands	0.336	0.292	0.250	0.346	0.341
Balearic Islands	0.326	0.281	0.264	0.331	0.344

Categorization:

0.00 – 0.20 Very low	0.20 – 0.40 Low	0.40 – 0.60 Medium	0.60 – 0.80 High	0.80 – 1.00 Very high

Source: SOCLIMPACT Deliverable Report D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

5.5. Economic Impacts on the Blue Economy Sectors

5.5.1. Tourism (Non-Market Analysis)

In order to analyse the reactions of tourists to the impacts of climate change and the preferences for adaptation policies, several hypothetical situations were posed to 224 tourists visiting Crete, whereby possible climate change impacts were outlined for the island (i.e., beach erosion, infectious diseases, forest fires, marine biodiversity loss, heat waves, etc.).

Firstly, tourists had to indicate whether they would keep their plans to stay at the island or find an alternate destination if the impact had occurred, which allows predictions of the effects on tourism arrivals to be made for each island. Secondly, tourists were asked to choose between various policy measures funded through an additional payment per day of stay – the tourists' choices being an expression of their preferences for attributes/policies. To estimate the results, the conditional logit model was run by using the Stata software (see **Figure 5.19**).

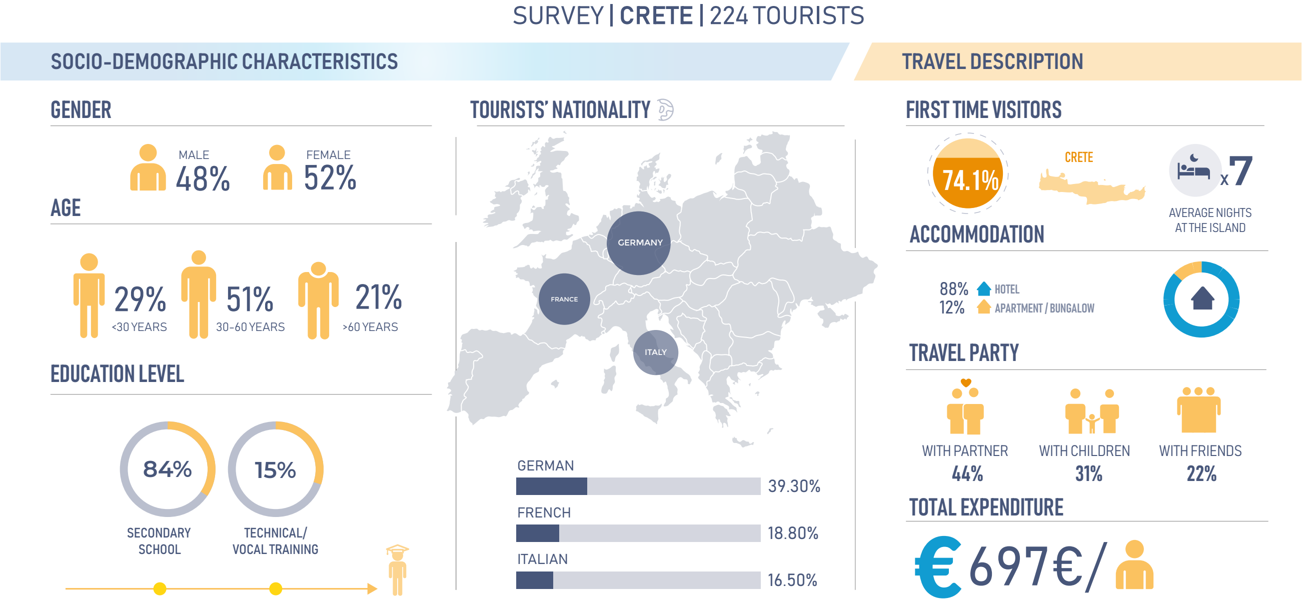


Figure 5.19. Socio-economic characteristics and travel description: tourists visiting Crete.

Source: SOCLIMPACT Deliverable Report - D5.5. Report on market and non-market costs of Climate Change and benefits of climate actions for Europe.

In general, data confirms that tourists are highly averse to the risk of wildfires occurring more often (26.80% of tourists would change destination). Moreover, they are not willing to visit islands where infectious diseases become more widespread (23.20%) or the cultural heritage is damaged due to weather conditions (17.40%). On the other hand, policies related to land habitat restoration (2.4€/day), the prevention of infectious diseases (2€/day), and coastal infrastructures protection (1.8€/day) are the most valued, on average, by tourists visiting this island.

Although climate change impacts are outside the control of tourism practitioners and policy-makers, they can nevertheless utilise this knowledge to improve the predictability of the effect that certain adaptation policies and risk management strategies, and develop their plans accordingly (see **Figure 5.20**).

The impact of increased temperatures and heat waves on hotels' prices and revenues

In order to assess how the variation in temperature impacts on the tourism sector through changes in tourism demand, our research question was: "How do increasing temperatures (and heat waves) impact prices and, more in general, expenditure of tourists?" Arguably, when temperatures grow, tourists adjust their behaviour: they might switch destination, or they might stay longer or shorter depending on their attitudes and preferences. In turn, all these changes modify the market equilibrium, pushing tourism companies to adjust their prices to re-establish the equilibrium between demand and supply. The change in demand and the change in price determine the change in tourism expenditure which is, from the destination's perspective, tourism revenue.

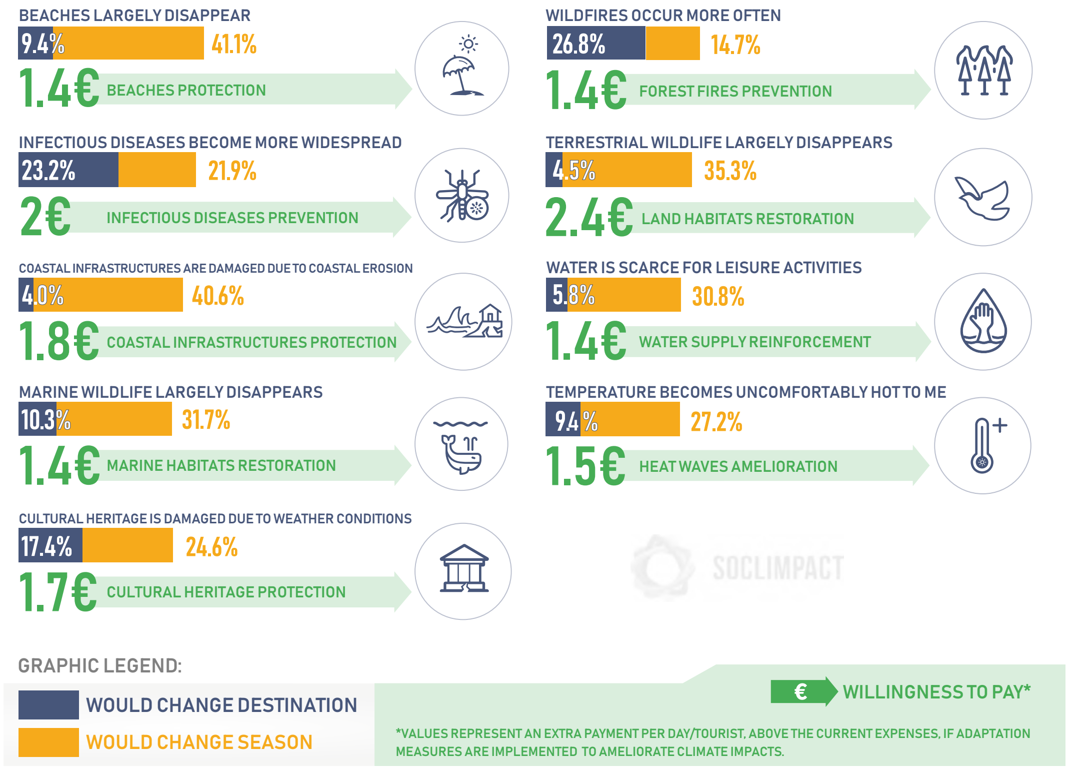


Figure 5.20. Tourists' response to climate change impacts and related policies: tourists visiting Crete.
Source: SOCLIMPACT Deliverable Report - D5.5. Report on market and non-market costs of Climate Change and benefits of climate actions for Europe.

We monitored current weather conditions posted on several weather forecast providers and daily prices posted on Booking.com by hotels. We then estimated the link between daily temperature and daily price, controlling for all the other factors affecting prices. We finally applied these estimates to the increase in the number of days with excessive temperature projected for the future in two scenarios (RCP2.6 and RCP8.5) and in two time horizons (near future, about 2050, and distant future, about 2100).

Among the different indicators linked to thermal stress, we focus on two: the number of days in which the temperature is above the 98^{th} percentile and the number of days in which the perceived temperature is above 35 °C. Although the impact for both indices was computed, in this document we only report the second one (named Humidex) because it is the most intuitive, and because human thermal stress is more related to the absolute value of the temperature than its deviation from some pre-determined distribution. We assumed that thermal stress appears when the perceived temperature grows above 35 °C.

As thermal stress is delimited in the summer months, and this is when the great majority of tourists arrive in these islands, the whole analysis has been carried out in six months only: from May to October included. In other words, we assume that there is no thermal stress (and hence, no impact on tourism) in the rest of the year.

Initially, three islands were investigated: Corsica, Sardinia, and Sicily, given the massive amount of potential data. Other estimations were provided for Crete using the Index of Distance in Destination Image to position each island in a range that goes from Sardinia / Corsica on one side, and Sicily on the other side. Without entering the details of the extrapolation method, a summary of results is reported below (see **Table 5.6)**.

According to these findings, the average increase in temperature, which is correlated to a growing thermal stress for tourists, brings an economic advantage to tourism destinations. This is only an apparent contradiction with previous findings. This study does not neglect the fact that if islands are too hot, tourists will choose to move to other (cooler) destinations, that theoretically exist. Then, the increase in tourism (and tourism revenues) stem from the fact that, when the temperature is too hot, people would prefer to move to coastal areas (where the climatic conditions are more bearable) than staying inland or in cities. Future trends will also facilitate this pressure of tourism demand (think about the spreading of smart working activities where, in principle, the worker can relocate wherever he/she wants).

Table 5.6. Estimation of increase in average price and revenues for Crete.

Actual share of days in which Humidex > 35 degrees	Future scenario considered	Days in the corresponding scenario in which Humidex > 35 degrees	Increase in the average price	Increase in the tourism overnight stays	Increase in tourism revenues
17.15%	RCP 2.6 near	26.52%	2.2%	0.4%	2.7%
	RCP 2.6 far	27.95%	2.6%	0.5%	3.1%
	RCP 8.5 near	30.52%	3.2%	0.6%	3.9%
	RCP 8.5 far	56.44%	9.4%	1.9%	11.5%

Source: SOCLIMPACT Deliverable Report D5.3. Data Mining from Big Data Analysis.

5.5.2. Energy

Climate change may impose welfare reductions to the European islands' societies by affecting thermal comfort. Cooling Degree Days (CDD) are a measure of how much (in degrees), and for how long (in days), outdoor air temperature is higher than 21 °C. The CDD is used as a measure of the energy needed to cool buildings. The increase in CDD and the energy demand (GWh/year) for cooling are estimated for the islands under different scenarios of global climate change.

Under the high emissions scenario, it is expected that the CDD increase to 586 CDD. Under this situation, the increase in cooling energy demand is expected to be 216 % (see **Figure 5.21**).

The Standardized Precipitation Evapotranspiration Index (SPEI) is analysed as a representative indicator for increases in water demand for islands' residents, tourists and agriculture, while it also provides an indication on the available water stored in dams or underground resources. To estimate the increase of energy demand due to the increase in water demand, it was assumed that most of the islands will have to produce desalinated seawater (or groundwater) to meet further increases. Thus, the estimation of the increase in energy demand (GWh/year) to produce more drinking water has been done based on the energy consumption required to desalinate seawater.

Under the low emissions scenario (RCP2.6), there are not significant changes in the SPEI indicator, that will remain in its ¨normal¨ level, as it is nowadays. Nevertheless, an increase of 32 % in desalination energy demand is expected. Under RCP8.5, the scenario alerts on a severe aridity leading to an increase of 159% of the energy demand (see **Figure 5.22**).

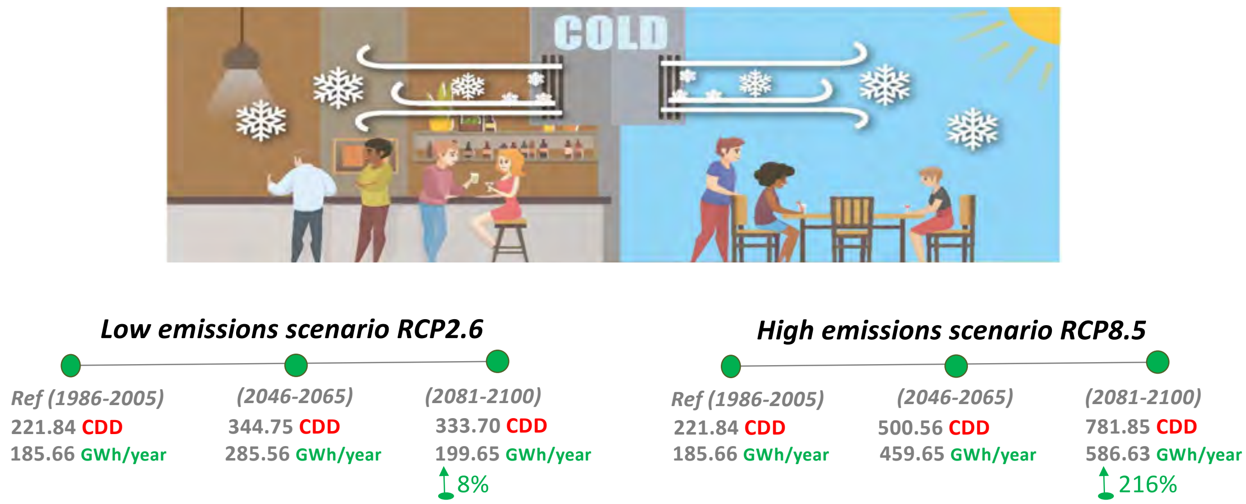


Figure 5.21. Estimations of increased energy demand for cooling in Crete under different scenarios of climate change until 2100.

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

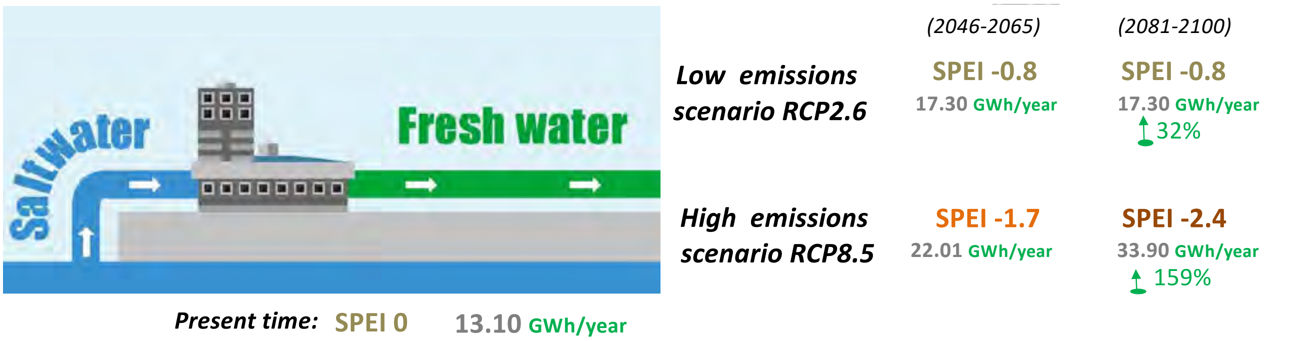


Figure 5.22. Estimations of increased energy demand for desalination in Crete under different scenarios of climate change until 2100.

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

5.5.3. Maritime Transport

For maritime transport, it has been estimated the impact of Sea Level Rise on ports' operability costs of the island. The costs have been calculated with reference to 1 meter; this is, the investment needed to increase the infrastructures' height by 1 meter. There is not necessarily a strict correspondence between the SLR and the required elevation of port infrastructures, which also depend on the coastal hydrodynamic and the shape of dikes of each port. By experts' recommendation, we have assumed that 1 meter increase in port height is required to cope with the SLR under RCP8.5 scenario of emissions. Extrapolation for other RCP scenarios is then conducted based on proportionality.

The starting point was the identification of the principal ports in each island (economic relevance). Secondly, the analysis of the different port areas (exterior, ramps, oil, etc.), and their uses. Thirdly, the elevation costs were estimated per each area and port separately (considering 1 meter elevation). Thus, the costs of 1 meter elevation presented are the sum of all areas and ports analysed, and including the rest of the ports of the island (if applicable) based on proportionality. Estimations consider that all ports areas of the entire area should be elevated at the same time. In other words, the economic values can be interpreted as the depreciation (amortization) costs of the investment needed to increase all ports' infrastructures in the island for a 125 years time horizon. No discount rate has been applied.

As expected, the rising of sea levels will affect the sector, as new investment will be needed to keep ports' operability. Under the high emissions scenario, it is expected that these costs could increase 1.26 million € per year until the end of the century (see **Figure 5.23**).

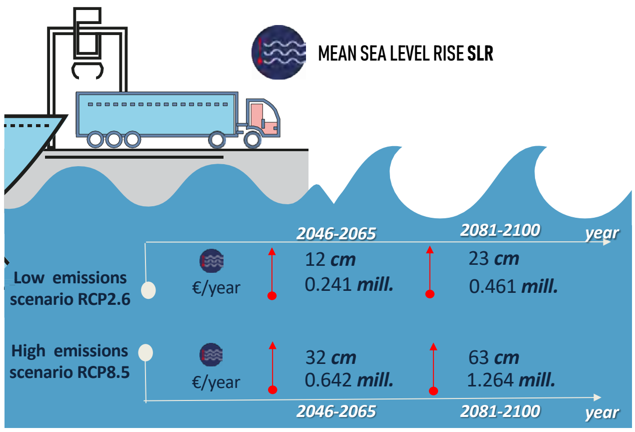


Figure 5.23. Increased costs for maintaining ports' operability in Crete under different scenarios of SLR caused by climate change until 2100.

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

5.6. Impacts on the Island's Socio-economic System

The aim of our study is to assess the socioeconomic impacts of biophysical changes for the island of Kriti. For this purpose, we have used the GEM-E3-ISL model, a single-region, multi-sectoral general equilibrium model based on the principles of neo-classical theory, and GINFORS, a macro-econometric model based on the principles of post-Keynesian theory.

Both models include 14 sectors of economic activity, with an emphasis on services and specifically on those composing the tourism industry. The GEM-E3-ISL model also includes endogenous representation of labor and capital markets as well as bilateral trade flows by sector.

Changes in the mean temperature, sea level and precipitation rates are expected to affect energy consumption, tourism flows and infrastructure developments. The impact on these three factors was used as input in the economic models, which then assess the effects on GDP, consumption, investments, employment, etc. These impact-chains have been examined and quantified under two emission pathways: RCP2.6, which is compatible with a temperature increase well below 2 °C by the end of the century, and RCP8.5, which is a high-emission scenario.

In total, 17 scenarios have been quantified for Kriti. The scenarios can be classified in the following categories:

1. Tourism scenarios: these scenarios examine the reduction in tourism revenues due to changes in human comfort as captured by the hum-index, the degradation of marine environment, the increased risk of forest fires and beach reduction. The aggregate tourism scenario (TOUR-SC6) assesses the economic impacts of a simultaneous change of all (the above-mentioned) factors.
2. Energy scenarios: the aggregate energy scenario (ENER-SC3) assessed the impacts on regional economic performance of increased total electricity demand driven by cooling and water desalination demand.
3. Infrastructure scenario: this scenario assesses the impact of port infrastructure damages (INFRA-MAR).
4. Aggregate scenarios: these scenarios examine the total impact of the previously described changes in the economy.

In the aggregate scenario, we examine the impacts of a simultaneous change in electricity consumption, tourism revenues and infrastructure damages. The scenario specifications for the two climatic variants are presented below (see **Table 5.7**).

The theoretical and structural differences of the two models mean that this study produces a reasonable range of impacts, given the uncertainty embodied in economic analysis and especially in the long-term.

In GEM-E3-ISL, the economy is in equilibrium at each point in time. Prices adjust to ensure that supply equals demand (market clearing) and capital is fully used; however, the model allows for equilibrium unemployment as it takes into account labor market rigidities. The impacts are driven mainly by the supply side through changes in production costs, which influence relative prices, hence, competitiveness and trigger substitution effects. The GEM-E3-ISL model assesses the impacts on the economy up to 2100.

Table 5.7. Aggregate scenario –inputs.

	Tourism revenues (% change from reference levels)	Electricity consumption (% change from reference levels)	Infrastructure damages (% of GDP)
RCP2.6 (2045-2060)	-11.21	3.80	-0.26
RCP2.6 (2080-2100)	-15.54	0.70	-0.25
RCP8.5 (2045-2060)	-39.19	10.30	-0.69
RCP8.5 (2080-2100)	-44.82	15.40	-0.68

Source: SOCLIMPACT Deliverable Report D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

The macro-econometric type of models, such as GINFORS, do not require that all markets are in equilibrium. Idle capital and involuntary unemployment are some other features of this type of models where the results are driven mainly by adjustments in the demand side of the economy. The GINFORS assesses the impacts on the economy up to 2050.

With respect to GDP, the estimated change compared to the reference case is between -1.1% and -1.3% in the RCP2.6 in 2050, and between -3.8% and -6.0% in the RCP8.5. The cumulative reduction over the period 2040-2100 is estimated (by GEM-E3-ISL) to be equal to 2.1% in the RCP2.6 and 7.9% in the RCP8.5 (see **Figure 5.24**).

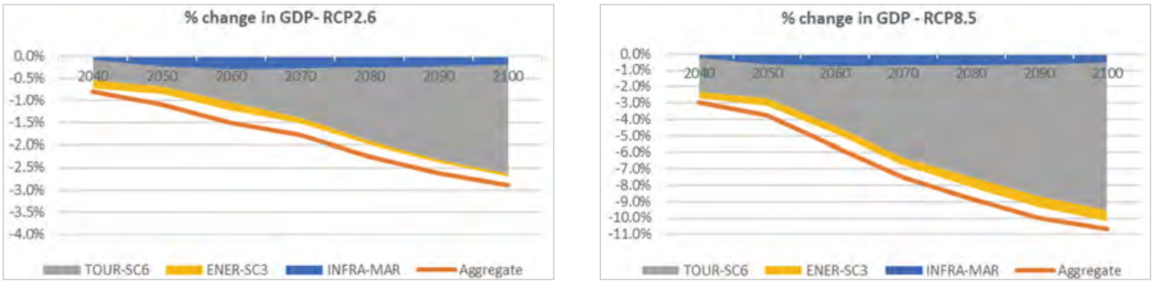


Figure 5.24. Percentage Change in GDP. GEM-E3-ISL results.
Source: own calculation. *(Continued on the next page)*

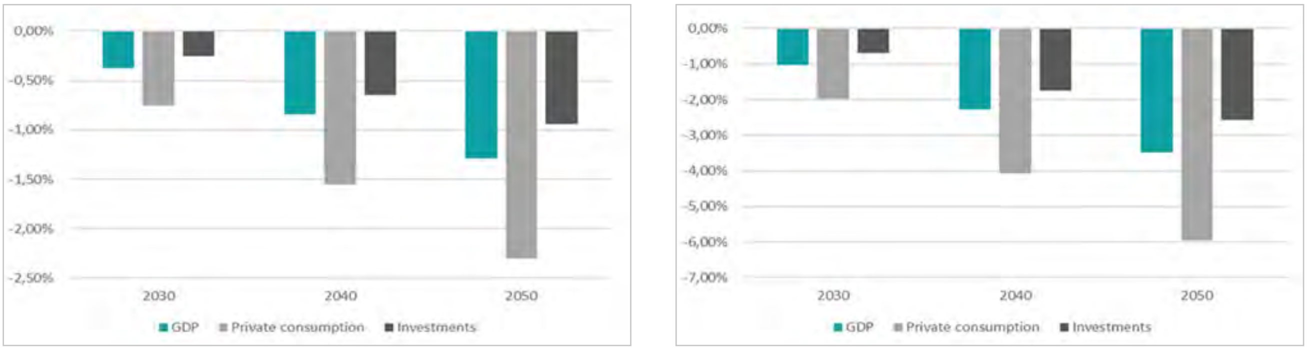


Figure 5.24 (Cont.). Percentage Change in GDP. GINFORS results.
Source: own calculation.

With respect to sectoral impacts, both models show a significant decrease in the activity of tourism related sectors and an increase in the activity of the manufacturing sector, highlighting the opportunities for the development of domestic manufactured products (see **Figure 5.25**).

Overall employment falls in the economy as the contribution of tourism in regional economy is quite significant, and the projected climate change impacts are projected to largely affect the influx of tourists. In GEM-E3-ISL, increases in employment in primary and secondary sectors and are attributed to

Figure 5.25. Production percentage change from reference. GEM-E3-ISL results (above), GINFORS (below).
Source: own calculation.

labor costs reductions (as wages fall and their competitiveness increases) and a consequent substitution of capital with labor. Employment falls on average by 0.75% in the RCP2.6 and by 2.5% in the RCP8.5 (see **Figure 5.26**).

Figure 5.26. Employment percentage change from reference. GEM-E3-ISL results (above), GINFORS (below).

Source: own calculation.

5.7. Towards Climate Resiliency

The development of a strategy for adapting to climate change is a national and regional obligation arising from the Framework Convention on Climate Change, commitments to the EU and the Paris Agreement on Climate Change.

The implementation of the national program for the reduction of greenhouse gas emissions for the period 2000-2010 was approved by the Council of Ministers with the act of 5 / 27.2.2003 (Government Gazette 58A / 5.3.03). In April 2016, the Ministry of Environment and Energy completed the National Strategy for Climate Change Adaptation (ESPKA). The country ratified the agreement on 06.10.2016 Paris (with Law 4426/2016, Government Gazette A'87) and submitted ratification documents on 14.10.2016.

According to article 43 of Law 4414/2016, the regions have the obligation to prepare Regional Plan for Adaptation to Climate Change (PESPKA). PESPKA is one integrated plan that identifies and prioritizes the necessary measures and actions of adaptation and in accordance with Regulation 1303/2013 / EU constitutes in advance a validity for implementation NSRF programs. The basic structure of PESPKA is defined in HA 11258 "Specialization Content of Regional Plans for Adaptation to Climate Change (PESPKA), according to Article 43 of Law 4414/2016 (A'149) "(Government Gazette 873B / 2017).

The Region of Crete is in the process of submitting a proposal for the Regional Adaptation Strategy for Climate Change. The objective of the Region of Crete is to draw up a plan that will provide answers around the actions that will have to be implemented against climate change, which affects everyday life, local economy, agriculture, livestock farming, fisheries, tourism and more.

According to the decision of the Regional Council 28/2015, the Smart Specialization Strategy of Crete (RIS3CRETE) was approved. This official text mentions how the Region of Crete will deal with climate change and how the policies of the region are generally integrated and interact.

In particular, the Smart Specialisation Strategy of the Region of Crete aims at using the potential of innovation and scientific knowledge in order to:

- Revitalise the agro-alimentary complex so as to adapt to climate change, strengthening of export branches and promotion of the value of Cretan nutrition which is Crete's intangible cultural heritage.

- Achieve the consolidation in the international market of a competitive cultural - tourism complex, with unique and original features.
- Reduce Crete's dependence on conventional forms of energy.
- Shift towards the sustainable use of the island's natural resources.
- Make the best of the sea's possibilities.
- Develop world-class educational and training activities for its human capital which will rely on Crete's educational web.
- Develop production activities of high added value in emerging sectors which will rely on Crete's educational web.

Reducing dependence on conventional energy sources through energy saving in buildings, lighting and infrastructures (wastewater and water management) and the full exploitation of the potential of renewable energy in the context of the particularities of Crete, in terms of sustainability. The Region of Crete is taking action by guidelines and proposed measures for water management in crops, as well as specific measures for adapting olive cultivation to climate change. In addition, it is in process to involve stakeholders in the preparation of adaptation policies mainly trough EU projects.

Specific limits and obstacles of the island in the fighinting against climate change can be summarized as follows:

- To date, spatial planning, urban planning and maritime spatial planning policies do not consider the impacts of climate change.
- Regional policies depend on national policies and national legislation to be followed. The main obstacles are slow procedures due to bureaucracy and funding constraints.
- There is a lack of reliable statistics and information related to exposure and vulnerability of the island to climate change. These are important components that worsen climate risks and respond to human interventions (more pressure). In particular, there is a lack of specific data to estimate climate change impacts and the costs of adaptation. The island's adaptation focus should be, first, the development of reliable information systems for the periodic monitoring of these components.

5.7.1. Policy Recommendations

A stakeholders consultation process was carried out in the island, aiming to propose, analyse and rank alternative adaptation measures for the island. The profile of the individuals participating in these focal groups involved policy and decision-makers, practitioners, non-governmental and civil society organisations, science experts, private sector, business operators and sector regulators at island level.

The main aim of these meetings was:

1. Identify and present the characterized packages of adaptation and risk management options for the island.
2. Develop detailed integrated adaptation pathways in three timeframes: Short term (up to 2030), Mid-century (up to 2050) and End-century (up to 2100).
3. Evaluate and rank adaptation options for 2 blue economy sectors in the island (maritime transport and tourism).

To this aim, stakeholders utilized five evaluation criteria to rank the proposed measures:

- Cost efficiency: Ability to efficiently address current or future climate hazards/risks in the most economical way.
- Environmental protection: Ability to protect the environment, now and in the future.
- Mitigation win-wins and trade-offs: Current ability to meet (win-win) or not (trade-off) the island / archipelagos mitigation objectives.
- Technical applicability: Current ability to technically implement the measure in the island.
- Social acceptability: Current social acceptability of the measure in the island.

Four scenarios of intervention were analysed, called Adaptation Policy Trajectories, which are different visions of future policy adaptation choices:

- APT A Minimum Intervention - Low investment, low commitment to policy change.
- APT B Economic Capacity Expansion - High investment, low commitment to policy change.
- APT C Efficiency Enhancement - Medium investment, medium commitment to policy change.
- APT D System Restructuring - High investment, high commitment to policy change.

It was assumed that adapting to climate change may range from minimal to high cost, and from requiring a small or incremental change to a significant transformation from the *status quo*. However, not all APT scenarios were considered in all islands, especially when their stakeholders had a clear vision on the types of measures with greatest viability. Therefore, the final set of proposed adaptation measures are framed in the islands' socio-economic and political context, have a sectoral perspective, and respond to the islands' future scenarios of climate change. At the same time, the involvement of regional stakeholders in policy design allows them to engage in the effective implementation of climate actions on their island.

In Appendices from K to N, a brief explanation of each adaptation option can be found, classified by type or class: Vulnerability Reduction, Disaster Risk Reduction, Social-Ecological Resilience, and Local Knowledge. The latest group refers to very specific measures proposed by stakeholders in each island to ratify the needs.

5.7.1.1. Tourism

Under APT B and D scenarios, the financial capital measures that were selected to address Vulnerability Reduction indicate that the region of Crete is initially centred on the development of economic policy Instruments and later on financial incentives to retreat from high-risk areas.

The option related with water restrictions and cuts was selected for all periods in a System Restructuring scenario (ATP D) and in an Efficiency Enhancement scenario (APT C). This obviously reflects the region's inability to take management measures for sustainable fishing as this depends exclusively on national and European regulations.

For Disaster Risk Reduction (DRR), and to manage long term risk, the decisions need to be sensible to the level of investment and reflects the climate change risk identified for the region. Coastal protection is a priority for the region throughout all the scenarios.

The Efficiency Enhancement scenario (ATP C) is the scenario which considers mainstreaming Disaster Risk Management (DRM) as a priority. This result, follows the risk response rational, addressing disasters management in a first stage. Health care delivery systems in Minimum Intervention scenario (APT A) over comes the fire management plans with small difference and reflects the climate-risk context of the region with the COVID-19 situation. Generically, to address DRR on tourism sector, it is necessary to continue to promote planning and allocate funds to develop climate change resilience in the region.

According to stakeholders, groundwater management is not urgent for the sector in the short term. The region should, in the next decades, invest efforts in information systems to improve climate information reliability. Options for regulation of natural services in the tourism sector will benefit from the maintenance of the rivers/valleys functions, creating recreational areas with a positive impact on tourism attractiveness.

In medium investment and medium commitment to policy change scenario (APT C - Efficiency Enhancement) the region considered to dedicate efforts to preserve and minimize the impacts on biodiversity and ecosystems, while also preserving the attractiveness of the region (see **Table 5.8**).

Table 5.8. Proposed adaptation options for tourism in Crete.

Pathway	Short-term (up to 2030)	Mid-century (up to 2050)	End-of-century (up to 2100)
APT A – Pathway — **Minimum Intervention** low investment, low commitment to policy change — This policy trajectory assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts	Public awareness programmes	Activity and product diversification	
	Drought and water conservation plans	Coastal protection structures	
	Fire management plans	Health care delivery systems	
	Post-disaster recovery funds	Pre-disaster early recovery planning	
	Monitoring, modelling and forecasting systems		Adaptation of groundwater management
APT B – Pathway — **Economic Capacity Expansion** high investment, low commitment to policy change — This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy	**Short-term (up to 2030)**	**Mid-century (up to 2050)**	**End-of-century (up to 2100)**
	Economic Policy Instruments (EPIs)		
	Activity and product diversification		
	Beach nourishment		Desalination
	Coastal protection structures		
	Monitoring, modelling and forecasting systems		Adaptation of groundwater management
	Dune restoration and rehabilitation	River rehabilitation and restoration	
APT C – Pathway — **Efficiency Enhancement** medium investment, medium commitment to policy change — This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system	**Short-term (up to 2030)**	**Mid-century (up to 2050)**	**End-of-century (up to 2100)**
	Public awareness programmes	Activity and product diversification	
	Local circular economy		
	Water restrictions, consumption cuts and grey-water recycling		
	Drought and water conservation plans	Coastal protection structures	
	Mainstreaming Disaster Risk Management		
	Adaptation of groundwater management	Monitoring, modelling and forecasting systems	
	River rehabilitation and restoration	Dune restoration and rehabilitation	
	Adaptive management of natural habitats	Ocean pools	Adaptive management of natural habitats

Table 5.8 (Cont.). Proposed adaptation options for tourism in Crete.

APT D – Pathway	Short-term (up to 2030)	Mid-century (up to 2050)	End-of-century (up to 2100)
System Restructuring high investment, high commitment to policy change — This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems	Financial incentives to retreat from high-risk areas	Economic Policy Instruments (EPIs)	
	Activity and product diversification		
	Water restrictions, consumption cuts and grey-water recycling		
	Drought and water conservation plans	Coastal protection structures	
	Post-disaster recovery funds	Pre-disaster early recovery planning	
	Monitoring, modelling and forecasting systems		Adaptation of groundwater management

Vulnerability Reduction | *Disaster Risk Reduction* | *Socio-Ecological Resilience* | *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

5.7.1.2. Maritime transport

The maritime transport sector adaptation pathways are characterized by a heterogeneity across the four potential adaptation policy trajectories (APTs) which they built upon. Regarding Vulnerability Reduction under APT B and D scenarios, the region of Crete is initially centred on financial incentives to retreat from high-risk areas. Social dialogue for training in the port sector and the trade diversification and climate resilient jobs are all priorities.

Under the Efficiency Enhancing (APT C) scenario (medium investment and medium change in policy commitment) and the System Restructuring (APT D), after an initial focus on the preservation of marketable natural resources via the investment in refrigeration and/or cooling systems there is a shift to restrictions to the development in high-risk areas.

Crete's maritime transport pathway favours investments in the operationality and flexibility of ports in detriment of improvement on vessels. Disaster Risk Reduction focused on managing risks via climate proofing of infrastructure and activities, while developing alternative routes during extremes events as a means of assuring Post-disaster recovery. This strategy is complemented by disaster responses that include new procedures to handle service disturbances and the development of early warning systems.

Ecosystem resilience and provisioning services take the form of tailored protection structures, mainly by using marine life friendly materials and coastal protection structures (see **Table 5.9**).

Table 5.9. Proposed adaptation options for maritime transport in Crete.

APT A – Pathway	Short-term (up to 2030)	Mid-century (up to 2050)	End-of-century (up to 2100)
Minimum Intervention low investment, low commitment to policy change — This policy trajectory assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts	Social dialogue for training in the port sector		Awareness campaigns for behavioural change
	Climate proof ports and port activities		
	Prepare for service delays or cancellations		
	Backup routes and infrastructures during extreme weather		
	Marine life friendly coastal protection structures		Combined protection and wave energy infrastructures
APT B – Pathway	**Short-term (up to 2030)**	**Mid-century (up to 2050)**	**End-of-century (up to 2100)**
Economic Capacity Expansion high investment, low commitment to policy change — This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy	Financial incentives to retreat from high-risk areas		Insurance mechanisms for ports
	Social dialogue for training in the port sector		
	Sturdiness improvement of vessels		Increase operational speed and flexibility in ports
	Climate proof ports and port activities		Consider expansion/retreat of ports in urban planning
	Marine life friendly coastal protection structures	Combined protection and wave energy infrastructures	
	Coastal protection structures	Hybrid and full electric ship propulsion	

Table 5.9 (Cont.). Proposed adaptation options for maritime transport in Crete.

<table>
<tr><td rowspan="9">APT C – Pathway
—
Efficiency Enhancement
medium investment, medium commitment to policy change
—
This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td colspan="2">Social dialogue for training in the port sector</td><td>Awareness campaigns for behavioural change</td></tr>
<tr><td>Climate resilient economy and jobs</td><td>Diversification of trade using climate resilient commodities</td><td>Climate resilient economy and jobs</td></tr>
<tr><td colspan="2">Refrigeration, cooling and ventilation systems</td><td>Restrict development and settlement in low-lying areas</td></tr>
<tr><td colspan="2">Climate proof ports and port activities</td><td>Consider expansion/retreat of ports in urban planning</td></tr>
<tr><td>Reinforcement of inspection, repair and maintenance of infrastructures</td><td colspan="2">Early Warning Systems (EWS) and climate change monitoring</td></tr>
<tr><td colspan="2">Marine life friendly coastal protection structures</td><td>Combined protection and wave energy infrastructures</td></tr>
<tr><td colspan="2">Coastal protection structures</td><td>Hybrid and full electric ship propulsion</td></tr>
<tr><td colspan="2">Integrate ports in urban tissue</td><td>Ocean pools</td></tr>
<tr><td rowspan="7">APT D – Pathway
—
System Restructuring
high investment, high commitment to policy change
—
This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td colspan="3">Financial incentives to retreat from high-risk areas</td></tr>
<tr><td colspan="3">Social dialogue for training in the port sector</td></tr>
<tr><td>Refrigeration, cooling and ventilation systems</td><td colspan="2">Restrict development and settlement in low-lying areas</td></tr>
<tr><td>Climate proof ports and port activities</td><td>Consider expansion/retreat of ports in urban planning</td><td>Climate proof ports and port activities</td></tr>
<tr><td>Post-disaster recovery funds</td><td colspan="2">Backup routes and infrastructures during extreme weather</td></tr>
<tr><td>Marine life friendly coastal protection structures</td><td colspan="2">Combined protection and wave energy infrastructures</td></tr>
</table>

Vulnerability Reduction | *Disaster Risk Reduction* | *Socio-Ecological Resilience* | *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

Chapter 6

Cyprus

SOCLIMPACT

This project has received funding from
the European Union's Horizon 2020 research
and innovation programme under
Grant Agreement No 776661

CONTENTS

Cyprus at a Glance

Cyprus is an island situated at the north-eastern end of the Mediterranean basin. It covers an area of 9,251 sq. km and stands at the crossroads of Europe, Africa, and Asia. It is the third largest island in the Mediterranean, smaller than Sicily and Sardinia, but larger than Corsica and Crete. It has a population of about 870,000, with the capital Lefkosia situated in the heart of the island. The island can be reached by air and sea transport, and the main means of transport on the island are cars, bicycles, and buses.

The main economic sectors estimated in 2018 are agriculture (2.3% of GDP), industry (14.1% of GDP) and services (83.6% of GDP). Tourism is the largest economy of the service sectors, with a total contribution of 21.9% towards the total GDP in 2018. According to Eurostat, the share of energy from RES amounted to 13.88% in 2018.

The Blue Economy Sectors

- **Aquaculture**

  Aquaculture in Cyprus constitutes an important component of its primary agricultural production, showing impressive growth rates and high-quality export products. As the global production of the capture fisheries sector decreases in the last twenty years and the demand for fishery products continues to grow, the contribution of aquaculture to the fishery products consumed worldwide each year has increased from about 10% in the '70s to around 50% in 2016.

- **Maritime Transport**

  Cyprus has over the years become one of the largest and widely known shipping centres in the world, comprising both ship owning and ship management companies. It is the largest third-party ship management centre in Europe and amongst the top three worldwide. Several of the ship management companies that operate on the island rank among the largest of their kind in the world and it is estimated that they manage about 20% of the world's third-party managed fleet.

- **Energy**

  Cyprus is an island with no exploited indigenous hydrocarbon energy sources. This means that its power generation system operates in isolation and totally relies on imported fuels for electricity generation. Currently, the primary imported fuel used in electricity generation is heavy fuel oil and gasoil. Cyprus' power generation system consists of three thermal power stations with a total installed capacity of 1480 MWe.

- **Tourism**

  The travel and tourism industry is the largest commercial sector of Cyprus, contributing 21.9% of the country's GDP in 2018. The number of tourist arrivals in 2017 reached 3,652,073 – corresponding to an increase of 14.6% from 2016. Europe is the traditional tourist market for Cyprus, with visitors from European countries constituting 87.5% of the total tourist arrivals in 2017, while visitors from European Union countries making up 59.7%. The United Kingdom is the most important source of tourism to the island and its share was 34.3% of the total tourist traffic in 2017, followed by Russia with 22.6%, Israel with 7.1%, Germany with 5.2%, and Greece with 4.6%. The total revenue from tourism during this period was estimated at €2,639.1 million compared to €2,363.4 million in 2016, recording an increase of 11.7%. The majority of tourists stated to have stayed in coastal areas of the island, such as Pafos and Polis, Ayia Napa, Paralimni, Larnaka, and Lemesos.

6.1. Current Climate and Risks

The main features of the Mediterranean climate of Cyprus are marked by hot and dry summers from mid-May to mid-September, rainy but mild winters from mid-November to mid-March, and two short autumn and spring transitional seasons of rapid change in weather conditions.

During summer, Cyprus is influenced by a shallow trough of low pressure, which has its centre in southwest Asia, resulting in high temperatures and clear skies. Rainfall is very low with an average value under 5% of the average total rainfall of the whole year. In winter, Cyprus is affected by the frequent passage of small depressions and fronts moving in the Mediterranean from west to east. These weather disturbances can last up to three days at a time and give the greatest amounts of precipitation. The total average rainfall during December-February corresponds to approximately 60% of the total rainfall of the year.

CURRENT CLIMATE-RELATED RISKS

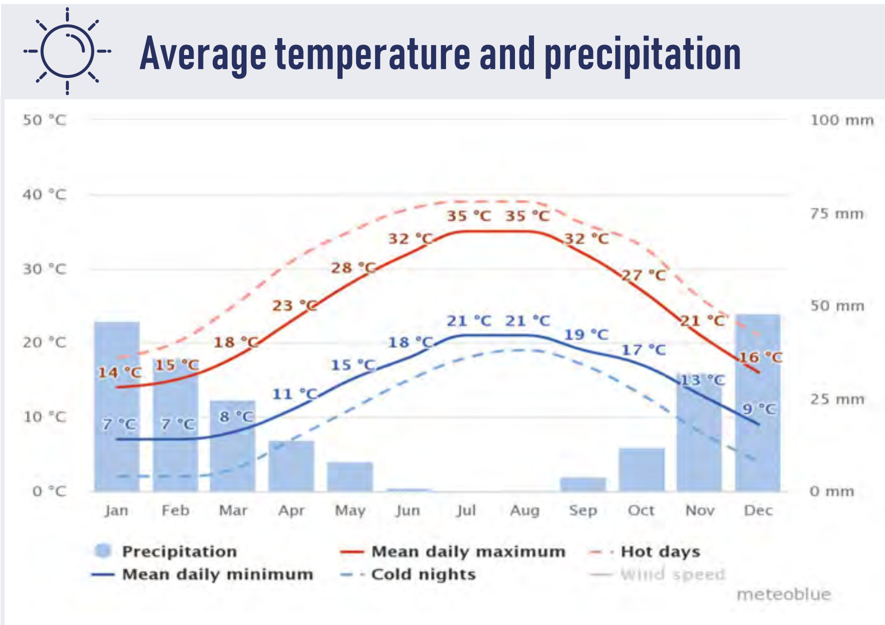
- Coastal flood High
- Wildfire High
- Extreme heat Medium

SIGNIFICANT CLIMATE EVENTS

- Heatwave (summer 2017)
- Drought (2018)
- Rainfall (2008, 2017)
- Floods (2013)

The central Troodos massif (at 1,951 meters) and, to a lesser extent, the Pentadaktylos mountain range (at roughly 1,000 meters) play an important role in shaping the meteorological conditions in the various regions of Cyprus and in creating local phenomena. The presence of the sea surrounding the island is also a cause of local phenomena in the coastal areas. This, together with high sunshine and mostly clear skies bring significant seasonal and daily variations in temperatures between the coastal regions and the inland areas (see **Figure 6.1**).

CLIMATE CHARACTERISTICS (35.18°N 33.36°E, 147m asl)



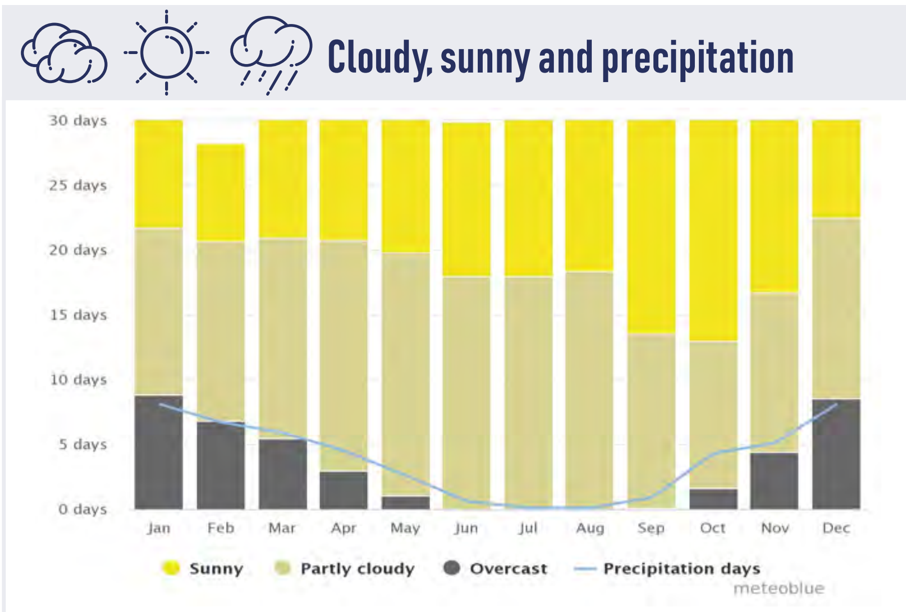
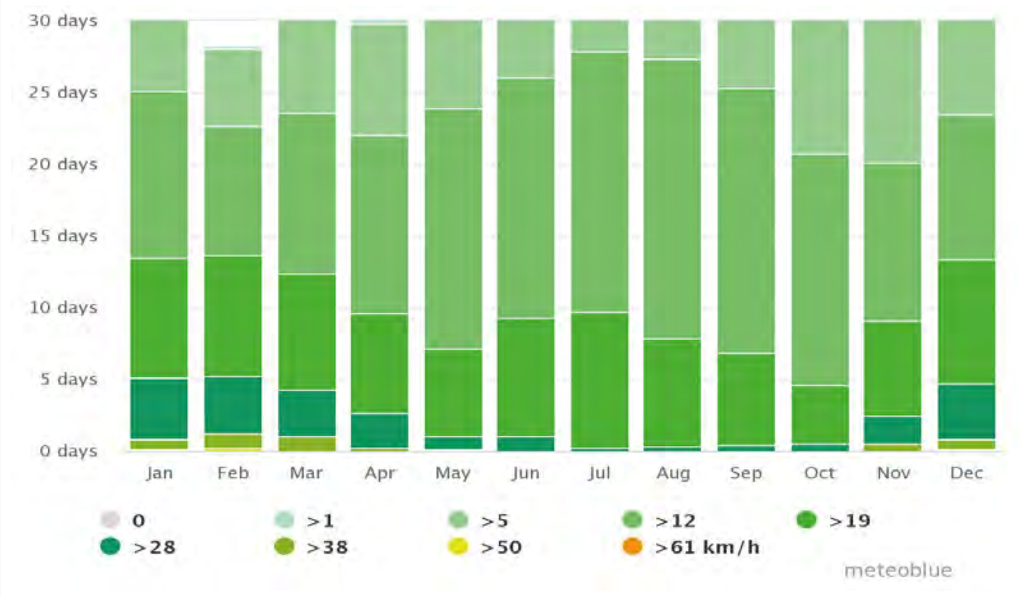


Figure 6.1. Climate factsheet.

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS. (NOAA Environmental Modeling System). **(Continued on the next page)**

Wind speed



Wind rose

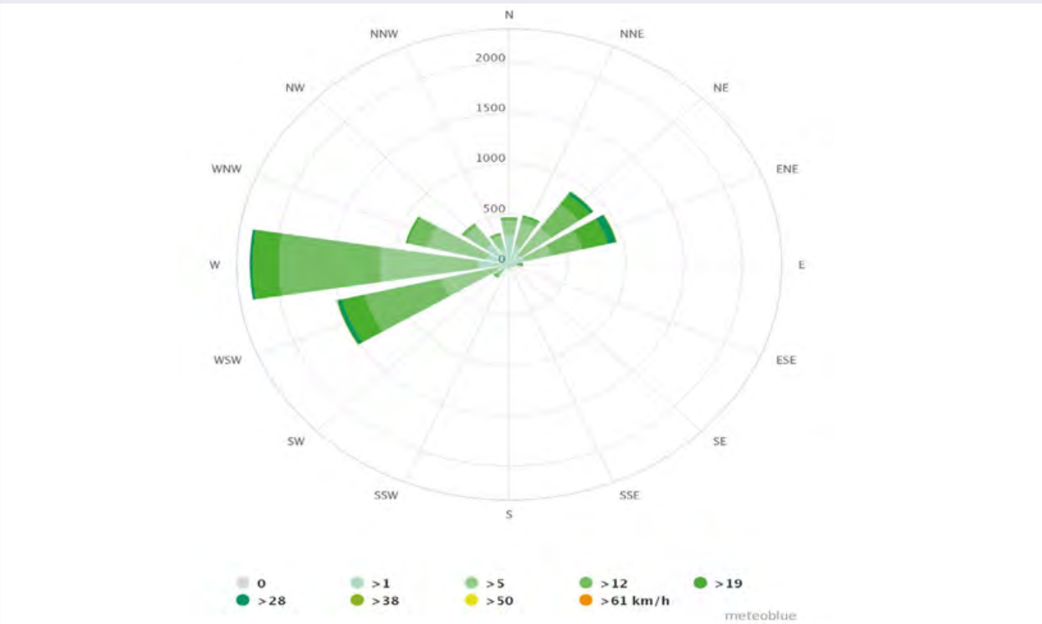


Figure 6.1 (Cont.). Climate factsheet.

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS. (NOAA Environmental Modeling System).

6.2. Macroeconomic Projections

According to the projections, Cyprus will continue to grow with an 1.8% yearly rate throughout the 2015-2100 period and 2.3% for the 2015-2050 period. The main driver of growth during the short-term period are investments while private consumption continues to play a key role (see **Table 6.1**).

Nevertheless, the contribution of private consumption to GDP is diminishing towards 2100, compensated by the growth of investments and an improved net trade position (see **Figure 6.2**). This indicates a transition towards a more sustainable economy that reduces its reliance on imported consumption and increases its productive capacity through investment activity. Investments grow with a high pace towards 2020, counterbalancing the lack of investments during the economic crisis, while presenting a stable growth rate throughout the 2025-2050 period, which is higher than that of GDP. We assume that the GDP-share of public consumption remains the same throughout the 2015-2100 period as Cyprus has already a privatized economy.

Table 6.1. Cyprus GDP and GDP components yearly growth rates in 2020-2100.

Growth rates of GDP components, 2020-2100										
	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
GDP	2.5%	2.1%	1.7%	2.5%	2.8%	2.4%	2.3%	1.1%	1.5%	1.6%
Private consumption	1.6%	1.9%	1.6%	2.0%	2.7%	2.1%	1.8%	1.2%	1.2%	1.6%
Public consumption	-0.8%	2.1%	1.7%	2.5%	2.8%	2.4%	2.3%	1.1%	1.5%	1.6%
Investments	9.9%	1.0%	1.2%	2.5%	2.3%	3.5%	2.7%	0.6%	2.5%	1.1%
Trade	2.7%	-1.4%	0.3%	-2.8%	1.1%	1.3%	-3.5%	-0.6%	0.9%	-4.6%

Source: SOCLIMPACT Deliverable D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

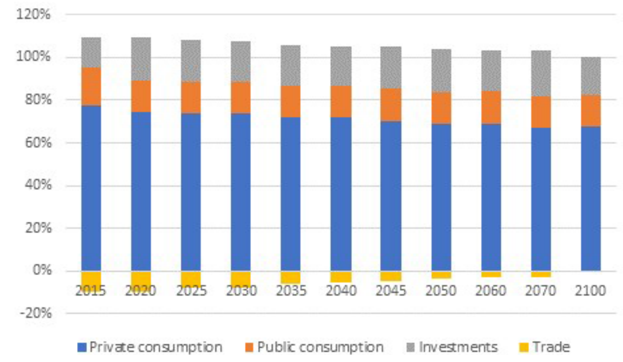


Figure 6.2. Macroeconomic components as a percentage share of GDP for Cyprus in 2015-2100.

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

6.2.1. The Sectoral Projections

The Cyprus economy remains a service-led economy throughout the 2015-2100 period (see **Table 6.2**), with an increasing contribution of market, accommodation and food services. Moving towards the end of the century, the share of primary and secondary sectors in gross value added (GVA) falls further to the benefit of sectors with higher value added. Demand for construction services increases in line with investment demand but with a lower growth rate, while transport services increase with a rate higher than GDP in order to enable the growing economic linkages of the island with the rest of the world.

Blue growth sectors increase in importance throughout the 2015-2100 period. In particular, the contribution of tourism in total value added grows from 20% in 2015 to 28% in 2100[1].

While the water transport sector grows steadily, travel agency and related activities register a declining share in total value added as they grow with a lower rate than that of GDP. Table 6.2 illustrates the changes to the sectoral decomposition of GVA for Cyprus from 2015 until the near future (2050) and the distant future (2100) (see **Figure 6.3**).

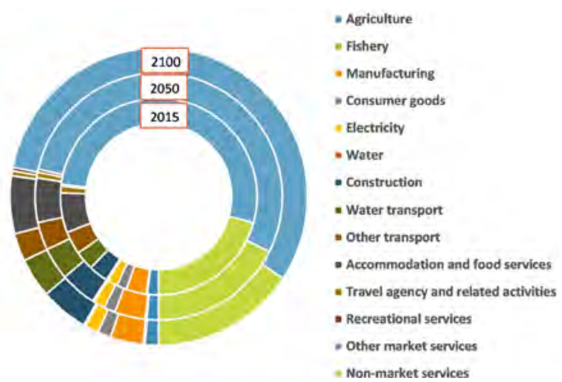


Figure 6.3. Sectoral contribution as a percentage share of total GVA for Cyprus (2015, 2050, 2100).

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

[1] The share of tourism in GDP is calculated via the tourism satellite account (TSA) matrices of 2015, assuming that the same shares that indicate the contribution of tourism to the productions of tourism-related sectors (such as the accommodation and food services, transport services, travel agency and related activities, cultural and recreational activities) remain throughout the 2015-2100 period.

Table 6.2. Sectoral contribution as a percentage share of total GVA for Cyprus in 2015-2100.

GVA% shares	2015	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
Agriculture	1.9%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.6%	1.6%	1.5%	1.5%
Fishery	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Manufacturing	3.3%	4.2%	4.3%	4.4%	4.1%	4.2%	4.4%	4.0%	3.5%	3.5%	3.6%
Consumer goods	1.7%	1.4%	1.4%	1.4%	1.4%	1.4%	1.3%	1.5%	1.6%	1.4%	1.4%
Electricity	1.7%	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%	1.5%	1.5%	1.5%	1.5%
Water	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Construction	3.2%	4.0%	3.9%	3.9%	4.5%	4.5%	4.8%	4.8%	4.8%	5.3%	5.2%
Water transport	3.2%	3.8%	4.0%	4.2%	4.4%	4.6%	4.9%	4.3%	3.9%	3.9%	4.3%
Other transports	3.8%	4.0%	4.1%	4.0%	3.4%	3.4%	3.4%	3.7%	3.4%	3.2%	3.1%
Accommodation and food services	6.4%	6.5%	6.6%	6.7%	6.4%	6.4%	6.2%	5.7%	6.0%	5.9%	6.2%
Travel agency and related activities	1.1%	0.9%	0.9%	0.9%	0.8%	0.7%	0.6%	0.7%	0.7%	0.6%	0.5%
Recreational services	0.3%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
Other market services	52.3%	53.0%	52.6%	52.1%	52.9%	53.0%	52.8%	53.8%	55.6%	56.6%	56.1%
Non-market services	20.7%	18.3%	18.4%	18.5%	18.2%	17.8%	17.5%	17.7%	16.7%	16.0%	15.8%

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

6.2.2. Employment

The service-led economic growth brings positive effects to the labour market with unemployment projected to fall from 15% in 2015 to more sustainable levels within a 20-year period. The contribution of each sector to total employment depends on the labour intensity of the sector. The biggest employing sectors are the market and non-market services as well as construction. Manufacturing and other transport sectors also retain their shares throughout the 2015-2100 period. Tourism is largest employer of the Blue growth sectors under analysis, particularly due to the high labour intensity of accommodation and food services. Water transport employs an only small share of total, and thus has the lowest contribution among the Blue growth sectors (see **Table 6.3** and **Figure 6.4**).

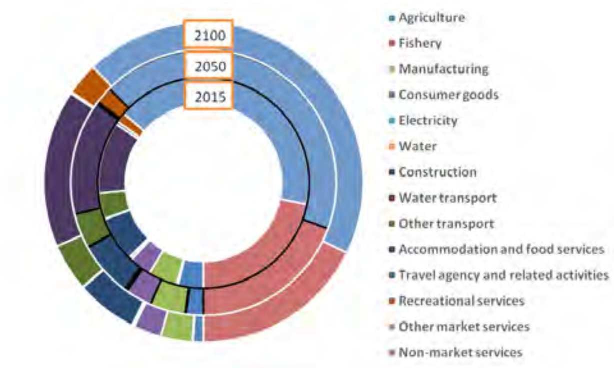


Figure 6.4. Sectoral employment as a% share of total for Cyprus (2015, 2050, 2100).

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

Table 6.3. Unemployment rate for Cyprus in 2020-2100.

	2015	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
Unemployment rate	15.0%	11.1%	9.8%	6.1%	5.9%	5.9%	5.9%	5.9%	5.7%	5.6%	5.8%

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

6.3. Climate Change Outlook

Climate hazards indicators represent the entry point to understand the climate change exposure of the blue economy sectors. The indicators have been computed for two scenario, RCP2.6 (low emission scenario) and RCP8.5 (high emission scenario) and for different horizon times namely: a reference period (1965-2005), mid-century (2046-2065) and end of century (2081-2100). Main source of climate projections (future climate) for Cyprus is EURO-CORDEX ensemble even if other model sources were applied when required, depending on available scales. Results are presented in form of maps, tables or graphs and only when the information shows an interesting outcome.

6.3.1. Tourism

One of the consequences of an increase in the mean sea level will be the flooding of coastal areas. This includes sand beaches, which are the main asset for tourism activities in most of the European islands. Therefore, estimating the potential risk of beach loss due to climate change is of paramount importance for the economy of those islands.

6.3.1.1. Extreme flood level (95th percentile of flood level averaged)

The 95th percentile of the flood level averaged was selected as an indicator of interest. The values are presented as anomalies with respect to the present mean sea level at beach location (i.e., including the median contribution of runup). In all cases, an increase is expected being larger at the end of the century under scenario RCP8.5. The values in that scenario are 92.47 cm in Cyprus. Under RCP2.6 scenario, the values are less than half, suggesting that a mitigation scenario could largely minimize the negative impact of climate change on beach flooding. Under mean conditions, we find that, at end of century, the total beach surface loss range from ~30 % under scenario RCP2.6 to ~54 % under scenario RCP8.5 (see **Figure 6.5**).

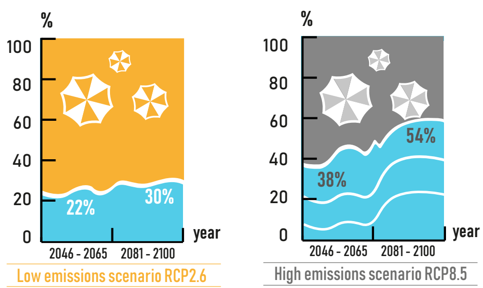


Figure 6.5. Beach reduction % (scaling approximation).

Source: SOCLIMPACT Deliverable Report - D4.4d. Report on the evolution of beaches.

6.3.1.2. Seagrass evolution

Seagrasses are the main habitat for coastal marine ecosystems. They provide different services like sediment retention (and thus, clearer waters), coastal protection (in front of marine storms), shelter for marine organisms, etc. Therefore, the state of the seagrasses is a convenient proxy for the state of coastal environment. That is, large well-preserved extensions of seagrasses lead to a better coastal marine environment which in turn is more resilient in front of hazards. Our results suggest that no seagrass losses are expected for the Posidonia located in the coasts of the island (see **Figure 6.6**).

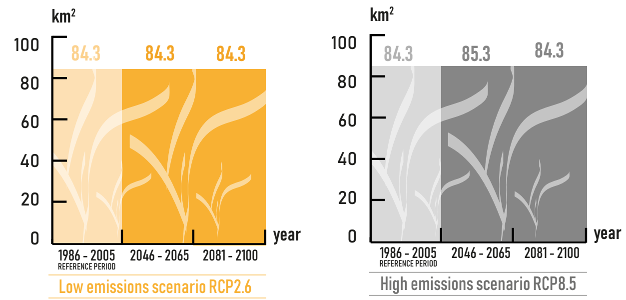


Figure 6.6. Projection of seagrass coverage.

Source: SOCLIMPACT Deliverable Report - D4.4e. Report on estimated seagrass density.

6.3.1.3. Length of the window of opportunity for vector-borne diseases - Vector suitability index for Aedes Albopictus (Asian Tiger Mosquito)

Climate change can influence the transmission of vector-borne diseases (VBDs) through altering the habitat suitability of insect vectors. This is mainly controlled by increases of ambient air temperature and changes in the hydrological cycle. We explore if potential changes to meteorological conditions can affect the distribution of the Asian tiger mosquito (Aedes albopictus). Asian tiger mosquito is native to the tropical and subtropical areas of Southeast Asia; however, in the past few decades, this species has spread to many countries through the international transport of goods and increased travel (Scholte and Schaffner, 2007). It is of great epidemiological importance since it can transmit viral pathogens and infectious agents that cause chikungunya, dengue fever, yellow fever and various encephalitides (Proestos *et al.*, 2015).

The multi-criteria decision support vector distribution model of Proestos *et al.* (2015) has been employed to estimate the regional habitat suitability maps. This is based on extending previous work on the environmental/climatic factors affecting the life cycle of the Asian tiger mosquito (Waldock *et al.*, 2013;

Proestos *et al.*, 2015). The mosquito habitat suitability model combines seven meteorological indices based on field observations, extensive literature review and expert knowledge.

According to figure, for the island of Cyprus located in the eastern Mediterranean, for the historical period the simulated climate conditions indicate a medium suitability according to our definition (HSI values of 68.7). This is expected to slightly increase in a future of strong climate change mitigation (pathway RCP2.6). On the contrary, under business-as-usual RCP8.5 the suitability is expected to decrease. For a large part of the island (mainly inland) the future climatic conditions will likely be unfavourable for the Asian tiger mosquito, while high suitability is mostly simulated over the mountainous areas of Troodos where summer temperatures are not expected to exceed the 40 °C threshold (see **Figure 6.7**).

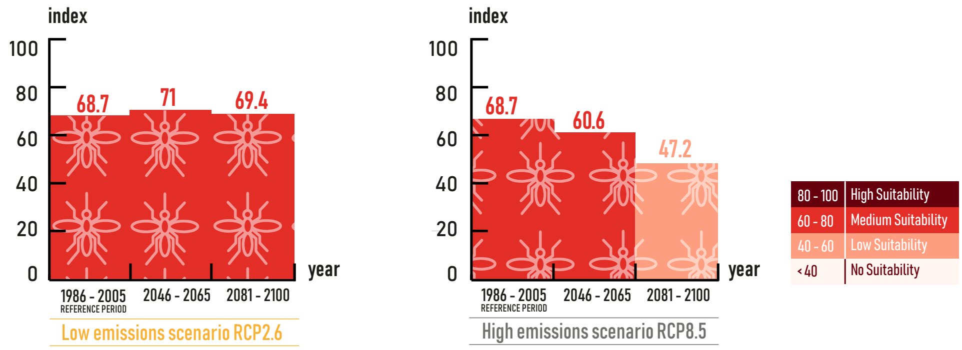


Figure 6.7. Habitat Suitability Index (HSI). 80-100: High Suitability; 60-80: Medium Suitability; 40-60: Low Suitability; <40 No Suitability.
Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed hazard indexes and indicators.

6.3.1.4. Fire Weather index (FWI)

The FWI system provides numerical non-dimensional ratings of relative fire potential for a generalized fuel type (mature pine stands) based solely on weather observations. FWI is part of the Canadian Forest Fire Danger Rating System established in Canada since 1971 (van Wagner, 1987). Furthermore, since 2007, FWI has been adopted at the EU level and used in a harmonized way throughout Europe by the European Forest Fire Information System (EFFIS) of the Copernicus Emergency Management Service (since 2015).

It is selected for exploring the mechanisms of fire danger change for the islands of interest, as it has been proved to adequately perform for several locations, including the Mediterranean basin. The index was calculated for the fire season (defined from May to October) over the Mediterranean for all models, scenarios and periods.

For Cyprus, N = 77 grid cells were retained from the model's domain. In the following figure, the ensemble means and the uncertainty are presented for all periods and RPCs. The fire danger for this island is the highest among the Mediterranean islands.

According to the model simulations, there are areas that already belong to very high fire danger class. It seems that under RCP2.6, the index slightly increases by 5%. On the other hand, under RCP8.5 the increase in fire danger exceeds 20% by the end of the century. Even if this increase is lower than in other islands, the majority of the island will be under high and very high fire danger (see **Figure 6.8**).

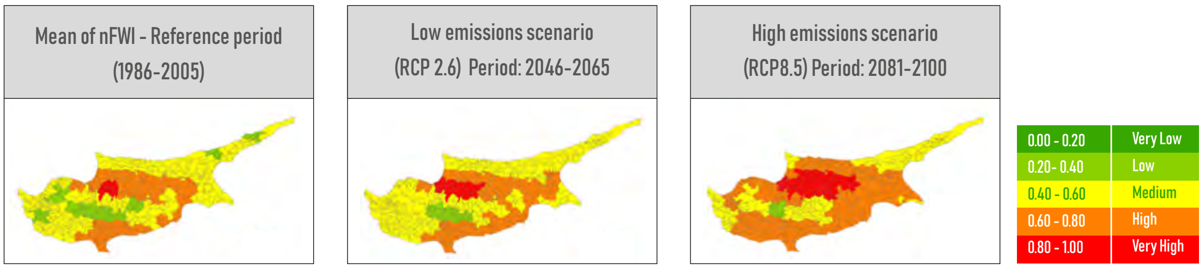
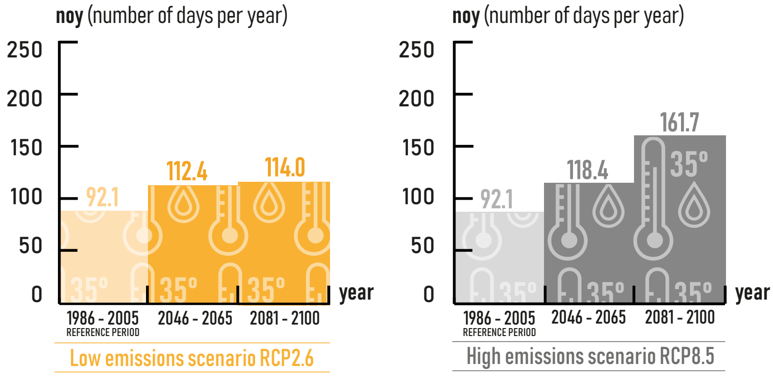


Figure 6.8. Fire Weather Index (EURO-CORDEX) with the colour associated to the level of risk.
Source: SOCLIMPACT Deliverable Report - D4.4c. Report on potential fire behaviour and exposure.

6.3.1.5. Humidex

For the assessment of climate hazard on heat related impacts of climate change on human health, the humidity index (Humidex) (Masterton and Richardson, 1979) has been used. Humidex value is an equivalent temperature, which express the temperature perceived by people (the one that the human body would feel), given the actual air temperature and relative humidity. As a more representative indicator for the assessment of inhabitants' and tourists' hazard on heat related climate change impacts, the Number of Days with Humidex greater than 35 °C was selected. From the above classification, a day with Humidex above 35 °C describes conditions from discomfort to imminent danger for humans.

For Cyprus, N = 77 grid cells were retained from the model's domain. In the present climate, the days with discomfort cover almost 3 months, with a small increase at the mid-century and for the RCP2.6, while respective number of days at the end of the century will correspond to more than 5 months (see **Figure 6.9**).



HUMIDITY	INDEX-DISCOMFORT LEVEL
<29°C	comfortable
30-34°C	some discomfort
35-39°C	discomfort; avoid intense exertion
40-45°C	great discomfort; avoid exertion
46-53°C	significant danger; avoid any activity
>54°C	imminent danger; heart stroke.

Figure 6.9. Number of days per year with Humidex > 35° C (Euro-CORDEX).
Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed hazard indexes and indicators.

6.3.2. Aquaculture

The predicted impacts of climate change on the oceans and seas of the planet are expected to have direct repercussions on marine based aquaculture systems. The basic effects are the following (Soto and Brugere, 2008):

- Change in biophysical characteristics of coastal areas.
- Increased invasions from alien species.
- Increased spread of diseases.
- Changes in the physiology of the cultivated species by changing temperature, salinity, oxygen availability and other important physical water parameters.
- Changes in the differences between sea and air temperature, which will alter the seasonality, frequency and severity of storms, cyclones and other extreme events, affect the stability of the coastal resources, and potentially increase the damages in infrastructure.

Sea level rise, acidification, changes in precipitation and other effects will also add to the changes in coastal ecosystems and environment, thus affecting production and infrastructure (investments).

Temperature changes in seawater trigger physical impacts, increased harmful algal blooms, decreased oxygen level, increase in diseases and parasites, changes in ranges of suitable species, increased growth rate, increased food conversion ratio and more extended growing season. Furthermore, all these impacts lead to socio-economic implications among them, changes in production levels and an increase in fouling and pests. The objective of the current analysis is to identify and quantify the variations (future climate scenarios with respect to present climate) in the number and in the duration of events characterized by a Sea Surface Temperature (SST) exceeding a given threshold. The SST thresholds have been identified according to the farming and feeding necessities of several marine species, particularly relevant for the aquaculture sector in the Mediterranean Sea (MS) (see **Figure 6.10**).

	Longest event (days) >20 degrees Mussels & clams	Longest event (days) >24 degrees Sea bream/Tuna	Longest event (days) >25 degrees Sea bass
Historic (1986-2005)	178 days	63 days	30 days
RCP 8.5 - mid century	197.5 days	105 days	81.5 days
RCP 8.5 - end century (2081-2100)	250 days	160.5	130 days

Species	Threshold (°C)
European seabass, Dicentrarchus labrax	25
Gilthead seabream, Sparus aurata	24
Amberjack, Seriola dumerili	23
Atlantic Bluefin tuna, Thunnus thynnus	23
Japanese clam, Ruditapes decussatus	21
Blue mussel, Mytilus edulis	21
Manila clam, Rudtape philippinarum	20
Mediterranean mussel, Mytilus galloprovinciales	20

Figure 6.10. Number of days per year Sea Surface Temperature (SST) exceeds a given threshold.

Source: SOCLIMPACT Deliverable Report - D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

6.3.3. Energy

A series of indicators related to renewable energy productivity is presented. The productivity and variability of these renewable energy sources will depend on climate. The possibility of reduced productivity due to climate change poses a risk to the energy generation if it is based on these renewable energy sources, as well as a possible increase in the frequency and duration of solar and wind energy.

6.3.3.1. Percentage of days when T > 98th percentile - T98p

The T98p is defined as the percentage of time where the mean daily temperature T is above the 98th percentile of mean daily temperature calculated for the reference period 1986-2005. For Cyprus, N = 77 grid cells were retained from the model's domain. In the following figure, the ensemble mean and the uncertainty are presented for all periods and RCPs.

It is found that T98p is about 7 % during RCP2.6 towards mid-century and slightly decreases at the end of the century, while for RCP8.5 more than 20 % of the year will exhibit temperatures above the 98th percentile (see **Figure 6.11**).

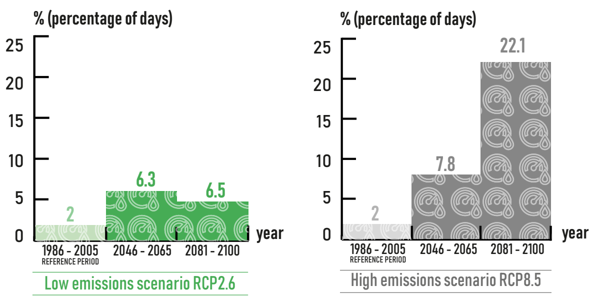


Figure 6.11. Percentage of days when T>98th percentile. Ensemble mean of EURO-CORDEX simulations.

Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed hazard indexes and indicators.

6.3.3.2. Renewable energy productivity indexes

A series of indicators related to renewable energy productivity is presented. The selected indicators are wind and photovoltaic (PV) energy productivity, as well as the frequency and duration of low-productivity periods, termed energy droughts (Raynaud *et al.*, 2018), as a measure of the variability of these sources. The productivity and variability of these renewable energy sources will depend on climate. The possibility of reduced productivity due to climate change poses a risk to the energy generation, if it is based on these renewable energy sources. Also, a possible increase in the frequency and duration of solar and wind energy droughts will require an increase in storage and backup sources.

Among the different renewable energy sources, solar PV and wind energy have been selected, as they are (and very likely will be) the main renewable energy sources, due to their degree of technological development and their comparatively low cost. In order to consider a marine energy source, offshore wind energy is included, in addition to onshore wind energy.

6.3.3.3. Photovoltaic energy productivity

Spatial differences between areas of the Cyprus Island can be appreciated, with minimum values in mountain regions. Changes in future periods are also different for that areas in comparison with the maritime area, where a generalized decrease is projected. Although some positive changes are seen over land in some areas, especially for the RCP8.5 scenario at the end of the century, spatially averaged changes over land are negative, although they are very small (less than 2 %). The higher decrease is projected also for the RCP8.5 scenario at the end of the century over the sea. In spatial average, it represents a 4 % of negative change (see **Figure 6.12**).

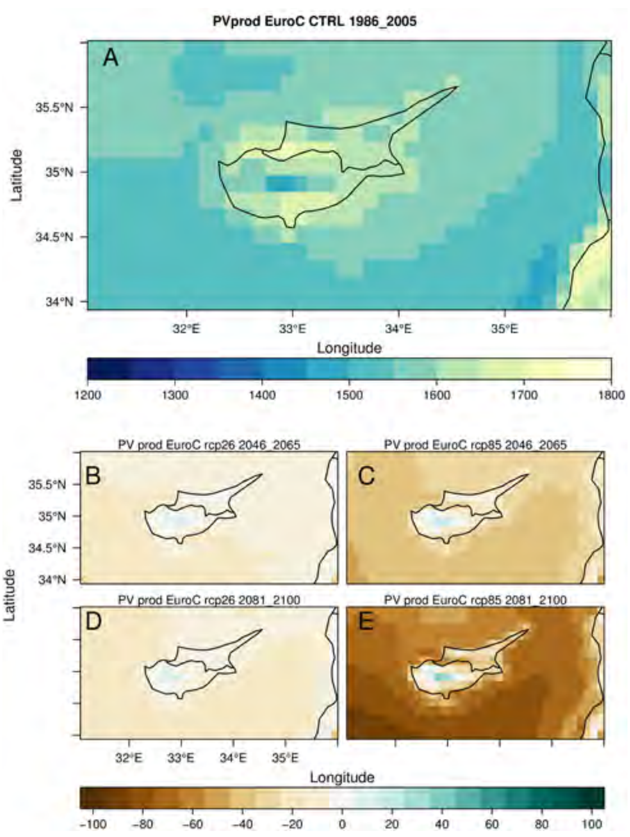


Figure 6.12. Panel A: Yearly mean photovoltaic productivity [kWh/kW] for the control time period (1986-2005). Panel B: Changes in yearly mean photovoltaic productivity in the RCP2.6 scenario for the 2046-2065 period with respect to the control. Panel C: As for panel B, but for the RCP8.5 scenario. Panel D: Changes in yearly mean photovoltaic productivity in the RCP2.6 scenario for the 2081-2100 period with respect to the control. Panel E: As for panel D, but for the RCP8.5 scenario.

Source: SOCLIMPACT Deliverable Report - D4.4a. Report on solar and wind energy for different scenarios and different time horizons.

6.3.3.4. Cooling Degree Days (CDD)

The Cooling Degree Days (CDD) index gives the number of degrees and number of days that the outside air temperature at a specific location is higher than a specified base temperature, providing the severity of the heat in a specific time period taking into consideration outdoor temperature and average room. For Cyprus, at the end of century, under RCP8.5, the increase of number of days is almost 150 %, that symbolizes the triple of the hindcast (see **Figure 6.13**).

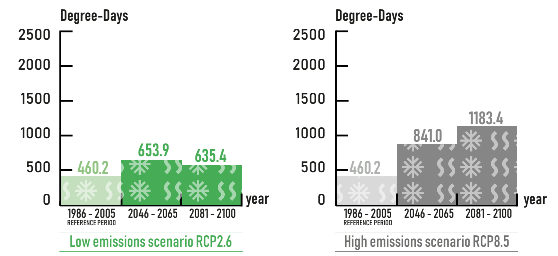


Figure 6.13. Cooling Degree Days. Ensemble mean of EURO-CORDEX simulations.

Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed hazard indexes and indicators.

6.3.3.5. Available water: Standardized precipitation index

This index is used as an indication of water availability. For Cyprus, only some regions of the north-east of the island are expected to be affected under RCP2.6 and exceed the "dry" conditions threshold. Under the business-as-usual RCP8.5 forcing, parts of the island are expected to experience extreme dry conditions that will be evident even from the mid-21st century. Mild changes are projected under RCP2.6, while under the business-as-usual scenario the whole island is expected to be severely affected by meteorological droughts (see **Figure 6.14**).

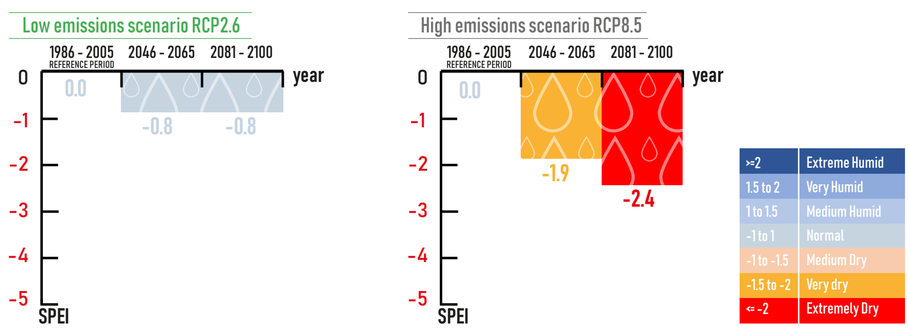


Figure 6.14. Ensemble mean, maximum and minimum values of the Standardized Precipitation Evaporation Index (SPEI) averaged over each SOCLIMPACT island and for each sub-period of analysis (EURO-CORDEX).

Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed hazard indexes and indicators.

6.3.4. Maritime Transport

6.3.4.1. Mean Sea Level Rise

Sea Level Rise (SLR) is one of the major threats linked to climate change. It would induce permanent flooding of coastal areas with a profound impact on society, economy and environment. Moreover, an increase in the mean sea level would result in a larger impact of coastal storms with the consequent increase of risk.

Several factors affect the evolution of mean sea level. At global scale, first, mass variations linked to the addition/removal of water from the ocean can be induced by land-based ice melting or by changes in the groundwater basically due to human activities. Second, thermal expansion due to ocean warming would also induce a rise of global mean sea level. Furthermore, regional changes are also expected and could induce a major contribution to total sea level rise at coastal scale. These are linked to the gravitational fingerprint of changes in the ocean mass, to changes in the circulation patterns (which in turn are related to the steric/density variations), to mass redistribution by atmospheric pressure and wind, and to land motion. All these factors cannot be modelled at the same time as they involve very different processes, so the typical approach is to use different models to cope with the different contributions. For Cyprus, the SLR ranges from 28.90 cm to 57.81 cm (RCP8.5) at the end of the century (see **Figure 6.15**).

6.3.4.2. Storm surge extremes

Storm surge events, characterized by positive extreme sea levels and mechanically forced by atmospheric pressure and wind, are the main responsible for coastal flooding, especially when combined with high tides. Different diagnostics can be used to characterize the storm surge events in terms of intensity, length or frequency and each option is suitable for different applications (i.e., infrastructure design would typically rely on return levels, while beach morphodynamics relies on percentiles). Nevertheless, previous studies have shown that the qualitative conclusions are equivalent and, as far as no clear thresholds have been defined for the impact chains, the simplest approach has been followed using the 95th percentile to define extreme sea level events.

To characterize storm surge high frequency (sub-daily) sea level data is required, which unfortunately is scarce. Most climate models provide only daily to monthly outputs so they cannot be used for this task. To date, the only ensemble populated with enough number of members to compute meaningful statistics on climate projections is the one produced for the Mediterranean by Lionello *et al.* (2017). This ensemble consists of 6 simulations run with the HYPSE model at 1/4° of spatial resolution and forced by the high-resolution wind fields from the MedCORDEX ensemble, which in turn is nested into CMIP5 global simulations. The simulations are run for the period 1950-2100, thus covering the historical period as well as the whole 21st century. Complementary, the ensemble includes three hindcast simulations that are used to establish present reference levels.

The results show a very low or even non-existent decrease except for RCP8.5 at the end of the century. Cyprus is the island where the value is the highest over the hindcast in the Mediterranean area but also the one with the lowest decrease in the far future (see **Figure 6.16**).

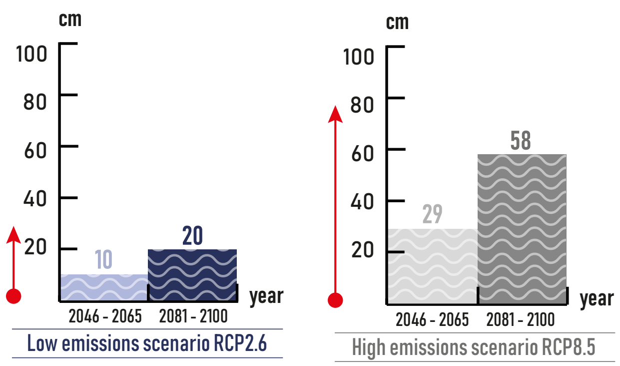


Figure 6.15. Mean sea level rise (in cm) with respect to the reference period (1986-2005). Own elaboration based on global and regional simulations.

Source: SOCLIMPACT Deliverable [Report - D4.4b](). Report on storm surge levels.

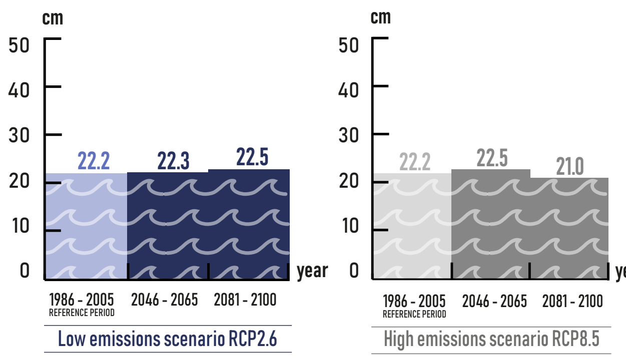


Figure 6.16. 99th percentile of atmospherically forced sea level (in cm) averaged for the hindcast period, the near future (2046-2065) and the far future (2081-2100) under scenarios RCP2.6 (with scaling approximation) and RCP8.5 and (relative change in %).

Source: SOCLIMPACT Deliverable [Report - D4.4b](). Report on storm surge levels.

6.3.4.3. Frequency of extreme high winds

This hazard indicator makes use of two indices:

- The wind extremity index (NWIX98), which is defined as the number of days per year exceeding the 98th percentile of mean daily wind speed (of the reference period 1986-2005), and
- The 98th percentile of daily wind speed (WIX98) around the islands, which is calculated for the same periods and scenarios as the NWIX98 indicator.

The indices were calculated for each island, model, scenario and period. The mean NWIX98 for each island is calculated for an area within about 50 km around the coastline (approximated as a rectangle). The land covered grid points of the islands themselves are not taken into consideration.

The calculation was performed for all available combinations of global (GCM) and regional (RCM) models. Their ensemble mean and uncertainty (described by the ensemble minimum and maximum) are provided for the reference period (1986-2005), as well as the two future periods of interest, mid-century (2046-2065) and end-century (2081-2100) for EURO and MENA–CORDEX simulations and for the reference period (1981-2000), as well as the selected future period (2031-2050) for ESCENA simulations.

The wind extremity index NWIX98 is defined as the number of days per year exceeding the 98th percentile of mean daily wind speed. This number decreases in the far future under RCP8.5 (- 22%).

Like the NWIX98, the 98th percentile of daily wind speed, WIX98, decreases for all islands except Crete and Fehmarn. However, the magnitude of the relative change is much smaller than for the NWIX98. The maximum magnitude of relative change in WIX98 is -3.8% for the island of Madeira at the end of the century under RCP8.5 compared to a change in NWIX98 of -32.3% for the same island, period and emission scenario (see **Figure 6.17**).

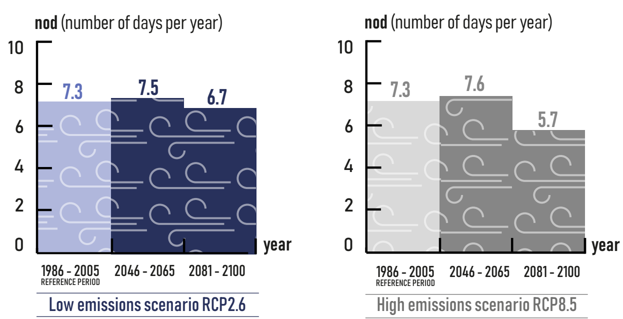


Figure 6.17. Wind Extremity Index (NWIX98). Ensemble mean of the EURO-CORDEX simulations.

Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed hazard indexes and indicators.

6.3.4.4. Wave extremes (99th percentile of significant wave height averaged)

Marine storms can have a negative impact on maritime transport, coastal-based tourism and aquaculture, among other activities. To illustrate this impact, the 99th percentile of significant wave height averaged has been chosen. A decrease in the extreme wave height is found being larger under scenario RCP8.5 as illustrated in the following map.

In relative terms, the averaged changes are lower than 10% even under the stronger scenario. The more significant change is observed under RCP8.5 at the end of century with -7%. (see **Figure 6.18**).

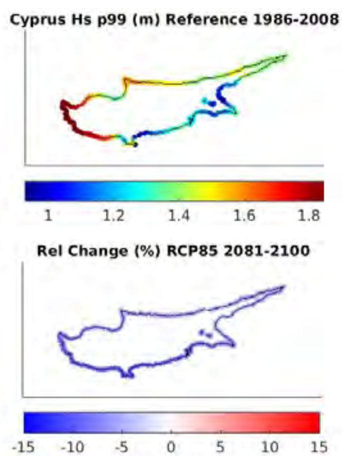


Figure 6.18. The 99th percentile of significant wave height averaged for the reference period and the relative change for the RCP8.5. Own elaboration based on global and regional simulations.

Source: SOCLIMPACT Deliverable Report - D4.4b. Report on storm surge levels.

6.4. Risk Assessment

6.4.1. Tourism

6.4.1.1. Loss of attractiveness due to increased danger of forest fires in touristic areas

For the reference period (1986-2005), the overall risk of forest fires is medium for Cyprus. Already in the near future (2046-2065), whatever the considered RCP, the risk increases only for Cyprus from medium to high. The same for the distant future (2081-2100), which continues to increase for both RCPs. This is mainly due to the predominance of the hazard component (fire danger), which is more prominent in eastern and southern areas of the Mediterranean, and continues to worsen over time (very high fire danger score in the distant future, together with medium score of vulnerability (medium flammability index). In the reference period, Cyprus has the highest risk, worsening in the distant future together with Crete as the regions with the highest risk of forest fires (see **Figure 6.19** and **Figure 6.20**).

Figure 6.19. Risk score at the end in the distant future (2081-2100) under RCP2.6 (Ambitious Mitigation Policies) and RCP8.5 (Business as usual).
Source: SOCLIMPACT Deliverable Report - D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

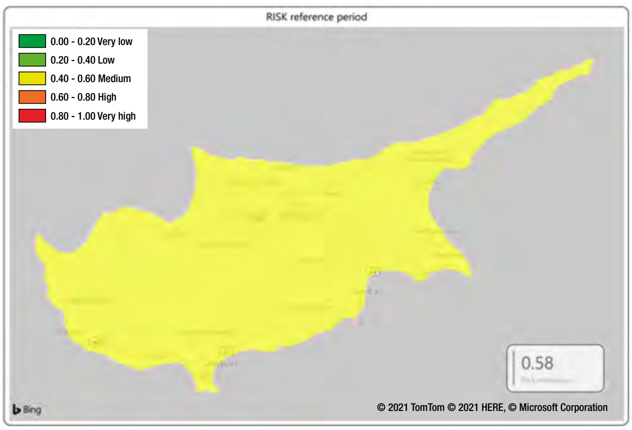


Figure 6.20. Risk score for the reference period.
Source: SOCLIMPACT Deliverable Report - D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

6.4.1.2. Loss of attractiveness due to marine habitats degradation

The position of Cyprus leading the ranking of the risk of its tourism industry to be negatively affected by seawater heating powered by climate change rests mostly on the two extremes of the impact chain under study. While the hazard explains the 23.6% of the risk, the deficits of the adaptive capacity explain another 67.7%, both giving account for more than the 91.3% of the risk. Although the island holds many cultural resources to decouple the generating of tourist value added from the marine environment conditions, some technical, institutional and historical factors prevent from going further this way so far. Reviewed information shows some projects and policies that have been undertaken to explore pathways for successful diversification, but it seems that the translation of the potentialities into effective policies has failed due to obstacles related to governance.

The mentioned advantages and disadvantages of Cyprus are depicted in the next figures. The further the criteria or sub-criteria is located from the centre of the graph, the more it affects the risk (see **Figure 6.21** and **Figure 6.22**).

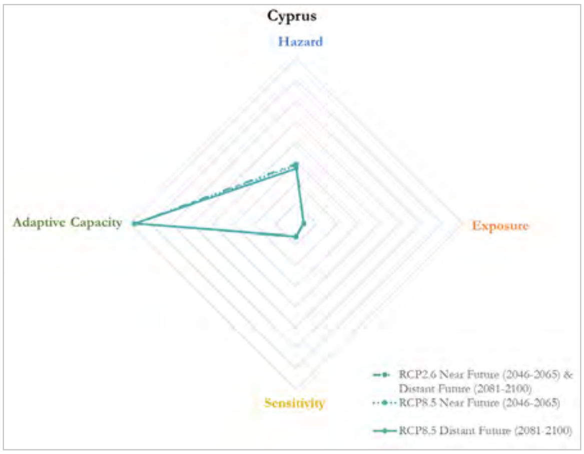


Figure 6.21. Global weights of each criteria and sub-criteria in the final score.

Source: SOCLIMPACT Deliverable [Report - D4.5](). Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

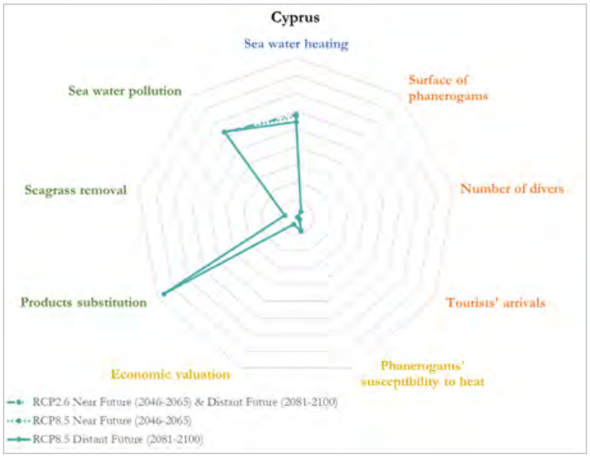


Figure 6.22. Global weights of each criteria and sub-criteria in the final score.

Source: SOCLIMPACT Deliverable [Report - D4.5](). Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

6.4.1.3. Loss of competitiveness of destinations due to a decrease in thermal comfort

Cyprus is at most risk of loss of competitiveness due to a decrease in thermal comfort in all four scenarios as it is ranked the highest in all cases. This is mainly attributed to the fact that the number of days with a heatwave is predicted to increase greatly both in the near and distant future. In addition, the island's tourist accommodations and facilities are located in areas more prone to heatwaves, and these are visited by many tourists during the months of May to September. Cyprus also scores the highest in sensitivity and average adaptive capacity.

The mentioned advantages and disadvantages of Cyprus are depicted in the next figure. The further the criteria or sub-criteria is located from the centre of the graph, the more it affects the risk (see **Figure 6.23** and **Figure 6.24**).

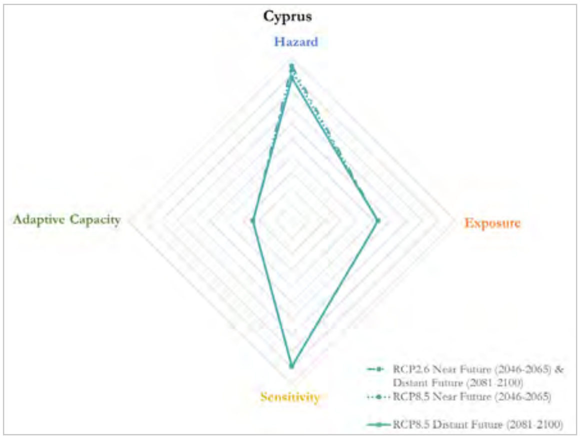


Figure 6.23. Global weights of each criteria and sub-criteria in the final score.

Source: SOCLIMPACT Deliverable [Report - D4.5](). Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

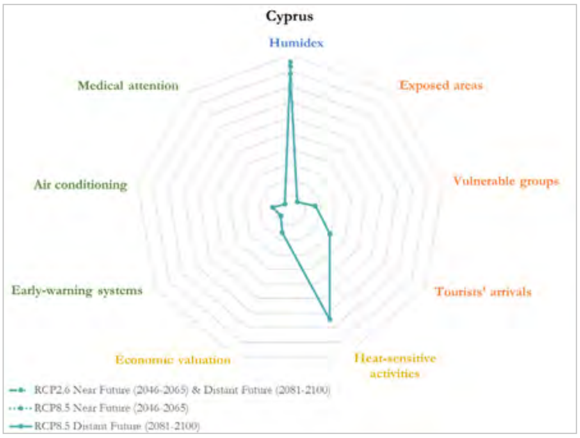


Figure 6.24. Global weights of each criteria and sub-criteria in the final score.

Source: SOCLIMPACT Deliverable [Report - D4.5](). Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

6.4.2. Aquaculture

6.4.2.1. Risk of increased fragility of aquaculture activity due to extreme weather events

Results for the hazard induced by mean wave motion appear to classify most Mediterranean offshore farm locations as semi-exposed sites (unlike those in the Atlantic, which are offshore). The probability of occurrence of extreme events that might prove unendurable for infrastructures moderately lowers the cumulative hazard. Results for Cyprus appear to be stable across time horizons and scenarios, probably due to the farm area being sheltered from extreme winds (see **Table 6.4**).

Table 6.4. Risk results for impact chain ¨Extreme Weather Events¨ for the Mediterranean islands.

Risk	Best-case scenario					Worst-case scenario				
	Reference period	Mid century		End century		Reference period	Mid century		End century	
	Hist.	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	Hist.	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Corsica	0.19	0.19	0.19	0.20	0.21	0.25	0.25	0.26	0.28	0.26
Cyprus	0.23	0.23	0.23	0.23	0.22	0.23	0.23	0.23	0.23	0.22
Malta	0.26	0.26	0.26	0.26	0.26	0.42	0.45	0.56	0.45	0.36
Sardinia	0.30	0.32	0.32	0.28	0.31	0.33	0.33	0.34	0.33	0.33
Sicily	0.20	0.20	0.20	0.20	0.20	0.30	0.34	0.33	0.33	0.26

6.4.3. Energy

Cyprus shows many differences compared to Crete, despite their relative proximity. The CDD score in Cyprus is nearly two times the score in Crete, for present climate and for RCP2.6 scenario, while for RCP8.5 it increases very strongly reaching the maximum value among all islands. For this high-emissions scenario, Cyprus would be the only island in which the threshold obtained by Jakubcionis *et al.* (2018) for full penetration of air conditioning equipment is exceeded by the end of the century (on average for the whole island). This highlights the strong increase in cooling energy demand expected under the high-emissions scenario.

SPEI scores would increase moderately under RCP2.6, with no change during the second half of the century, while a strong increase is expected under RCP8.5. In the latter case, the present percentage of desalinated water (between 4 and 31% from 2010-2017) would increase strongly.

Wind energy potential is much smaller than for Crete. Taken together with the very high score for wind energy droughts, wind energy could be considered as a rather low-quality energy resource. However, the scores are calculated from spatial and temporal averages of wind energy productivity, and some specific areas and seasons can show good wind energy potential. Koroneos *et al.* (2005) indicate that the southern coastal zone and certain exposed areas of the mountains are very promising for wind energy. Also, offshore wind energy near the southern coast of Cyprus is substantial in summer and shows a daily cycle with an afternoon/evening maximum (Tyrlis and Lelieveld, 2013) that, combined with PV, could match rather well the daily demand curve. This is important as maximum power demand occurs in summer.

Solar PV potential is high, and the productivity is very stable. In this case, a combination of PV and wind would be very beneficial in terms of stability of output, as the combined energy droughts (50/50 PV/wind energy) are at the very low level of solar PV.

Wind energy productivity projections show mostly some tendency of reduction, with relatively large reductions under RCP8.5 by the end of the century. Solar PV projections show either no change or small reductions in productivity (see **Table 6.5**).

Table 6.5. Risk scores for Cyprus: cooling and desalination energy demand, for the historical and future periods.

	Hist. ref.	RCP2.6 (2046-2065)	RCP2.6 (2081-2100)	RCP8.5 (2046-2065)	RCP8.5 (2081-2100)
Cooling	0.46	0.48	0.48	0.51	0.55
Desalination	0.40	0.41	0.41	0.43	0.44

Categorization:

0.00 – 0.20 Very low	0.20 – 0.40 Low	0.40 – 0.60 Medium	0.60 – 0.80 High	0.80 – 1.00 Very high

Source: SOCLIMPACT Deliverable Report - D4.5 Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

The risk associated to cooling energy demand currently shows a medium score, which does not increase much for RCP2.6 scenario. The increase for RCP8.5 scenario is much clearer. The weights of the different components indicate a higher importance for exposure indicators, followed by vulnerability and finally hazard indicators. The indicator showing the largest correlation is the ratio of the number of tourists to population, in stark contrast to Gran Canaria. Though the tourism seasonality is high, its influence on cooling energy demand is low, at least for the period considered. It should be taken into account that the available cooling energy demand data cover only a 9-years period (2010-2018), which is a source of uncertainty as impacts over longer time periods will not be captured. Likely as a result of this short period, the correlation of CDD with cooling demand is low, and the correlation of cooling demand to energy intensity is negative. It seems that the very strong increase in the number of tourists (nearly doubling from 2010 to 2018) has been enough to hide the influence of other factors. There is also little room for an increase of cooling demand linked to more air conditioning equipment, as the cooling penetration rate is already very high (80%).

The risk linked to desalination energy demand also presents now a medium score, and in these cases projected increases are very limited. This is due to the very low weight of the hazard component (SPEI) obtained through the correlation method, as the available desalination energy demand data cover only a limited period (2010-2017), in which the largest correlations are found for the percentage of desalinated water over total water, the GDP per capita and the number of tourists. SPEI may have a stronger impact over longer time-periods, as a sustained increase of temperatures and evaporation could show cumulative effects on desalination demand that outstrip other factors.

As a sensitivity calculation, we have obtained the desalination risk scores using equal weights for hazard, exposure and vulnerability. The risk score increases in this case by approximately 50% for RCP2.6, and more than doubles for RCP8.5 by the end of the century. This shows the strong dependency of risk scores on the applied weights.

6.4.4. Maritime Transport

For the eastern Mediterranean island of Cyprus and the risk of isolation due to maritime transport disruption, our analysis indicated low risk values (0.241) during the historical reference period. Greatest is the contribution that comes from the factors of adaptive capacity and nature of exposure. On the contrary, the hazard indicators related to the meteorological hazards had a much smaller contribution. For the mid of the 21st century, the risk for transport disruption remains low for both RCP2.6 and RCP8.5 (values of 0.21 and 0.258, respectively). The contribution of hazard indicators is becoming more significant, since mean sea level rise is increased compared to the default zero value of the historical reference period. Since the exposure indicators have the same values for both pathways, the differences in the risk values are mainly driven by the factors of adaptive capacity and mainly the contribution of renewables for this period. This contribution is expected to be more important in an RCP2.6 future, therefore, the risk values are somehow lower. For the end of the 21st century, the risk values do not change much for the optimistic RCP2.6. On the contrary, for RCP8.5 our analysis indicates an increase in the risk value (0.292), however this is still categorised in the low class (see **Table 6.6**).

Table 6.6. Summary of present and future risk of isolation due to maritime transport disruption for each island and scenario based on the Impact Chain operationalization.

Risk value per island	Historical reference	RCP2.6 MID	RCP2.6 END	RCP8.5 MID	RCP8.5 END
Cyprus	0.241	0.210	0.218	0.258	0.292
Crete	0.229	0.208	0.201	0.257	0.282
Malta	0.376	0.347	0.335	0.395	0.414
Corsica	0.220	0.194	0.194	0.243	0.273
Canary Islands	0.336	0.292	0.250	0.346	0.341
Balearic Islands	0.326	0.281	0.264	0.331	0.344

Categorization:

0.00 – 0.20 Very low	0.20 – 0.40 Low	0.40 – 0.60 Medium	0.60 – 0.80 High	0.80 – 1.00 Very high

Source: SOCLIMPACT Deliverable D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

6.5. Impacts on the Blue Economy Sectors

6.5.1. Tourism (Non-Market Analysis)

In order to analyse the reactions of tourists to the impacts of climate change and the preferences for adaptation policies, several hypothetical situations were posed to 258 tourists visiting Cyprus, whereby possible climate change impact were outlined for the island (i.e., beach erosion, infectious diseases, forest fires, marine biodiversity loss, heat waves, etc.) (see **Figure 6.25**).

Firstly, tourists had to indicate whether they would keep their plans to stay on the island or find an alternate destination if the impact had occurred, which allows predictions of the effects on tourism arrivals to be made for each island. Secondly, tourists were asked to choose between various policy measures funded through an additional payment per day of stay – the tourists' choices being an expression of their preferences for attributes/policies. To estimate the results, the conditional model was run by using the Stata software.

In general, data confirms that tourists are highly averse to risks of infectious diseases becoming more widespread (97.70 % of tourists would change destination). Moreover, they are not willing to visit islands where beaches largely disappear (84.50 %) or where temperature becomes uncomfortably hot (72.50 %). Consequently, policies related to beaches protection (11 €/day), heat waves amelioration (8.7 €/day), and the prevention of infectious diseases (6.9 €/day) are the most valued, on average, by tourists visiting this island.

Although climate change impacts are outside the control of tourism practitioners and policymakers, they can nevertheless utilise this knowledge to improve the predictability of the effect that certain adaptation policies and risk management strategies, and develop their plans accordingly (see **Figure 6.26**).

The impact of increased temperatures and heat waves on hotels' prices and revenues

In order to assess how the variation in temperature impacts on the tourism sector through changes in tourism demand, our research question was: "How do increasing temperatures (and heat waves) impact prices and, more in general, expenditure of tourists?" Arguably, when temperatures grow, tourists adjust their behaviour: they might switch destination, or they might stay longer or shorter depending on their attitudes and preferences. In turn, all these changes modify the market equilibrium, pushing tourism companies to adjust their prices to re-establish the equilibrium between demand and supply. The change in demand and the change in price determine the change in tourism expenditure which is, from the destination's perspective, tourism revenue.

We monitored current weather conditions posted on several weather forecast providers and daily prices posted on Booking.com by hotels. We then estimated the link between daily temperature and daily price, controlling for all the other factors affecting prices. We finally applied these estimates to the increase in the number of days with excessive tempera-

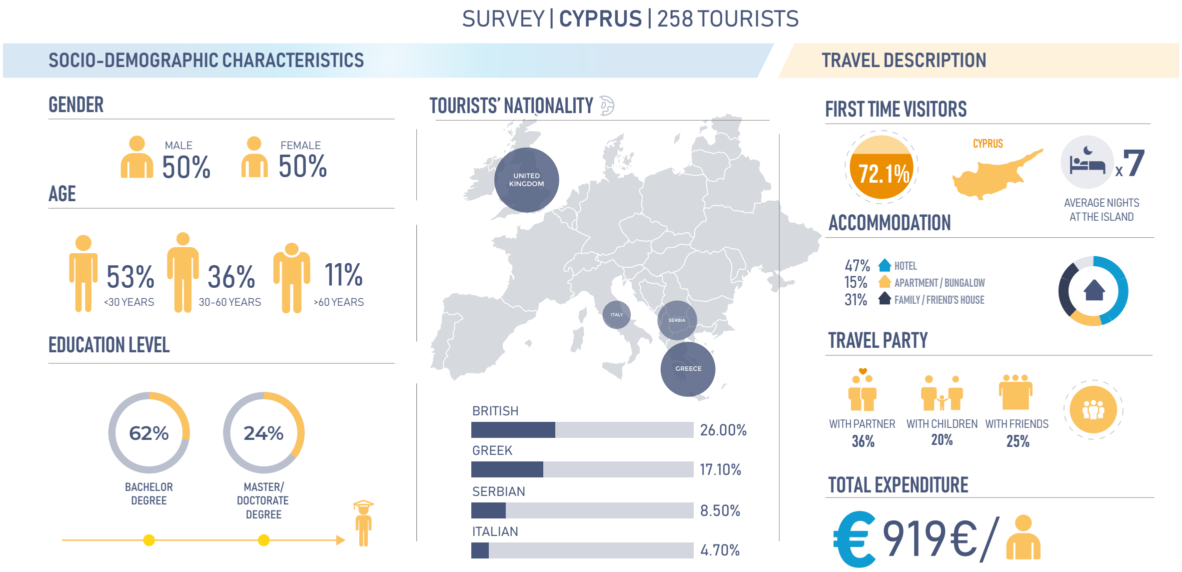


Figure 6.25. Socio-economic characteristics and travel description: tourists visiting Cyprus.

Source: SOCLIMPACT Deliverable Report - D5.5. Report on market and non-market costs of Climate Change and benefits of climate actions for Europe.

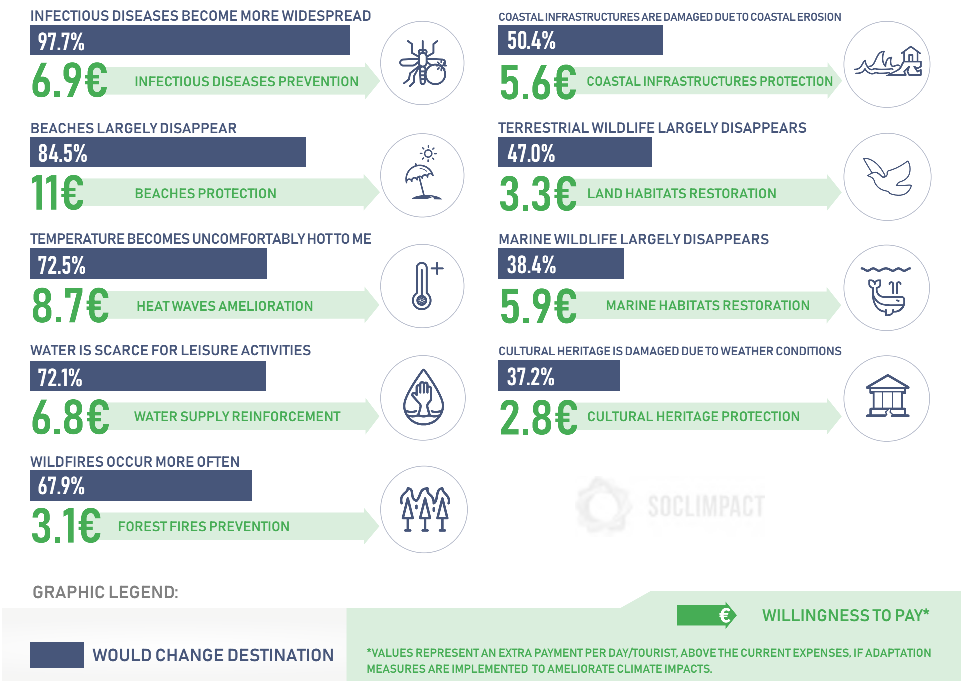


Figure 6.26. Tourists' response to climate change impacts and related policies: tourists visiting Cyprus.
Source: SOCLIMPACT Deliverable Report - D5.5. Report on market and non-market costs of Climate Change and benefits of climate actions for Europe.

ture projected for the future in two scenarios (RCP2.6 and RCP8.5) and in two time horizons (near future, about 2050, and distant future, about 2100).

Among the different indicators linked to thermal stress, we focus on two: the number of days in which the temperature is above the 98th percentile and the number of days in which the perceived temperature is above 35 °C. Although the impact for both indices was computed, in this document we only report the second one (named Humidex) because it is the most intuitive and because human thermal stress is more related to the absolute value of the temperature than its deviation from some pre-determined distribution. We assumed that thermal stress appears when the perceived temperature grows above 35 °C.

As thermal stress is delimited in the summer months, and this is when the great majority of tourists arrive in these islands, the whole analysis has been carried out in six months only, from May to October included. In other words, we assume that there is no thermal stress (and hence, no impact on tourism) in the rest of the year.

Initially, three islands were investigated: Corsica, Sardinia, and Sicily, given the massive amount of potential data. Other estimations were provided for Cyprus using the Index of Distance in Destination Image to position each island in a range that goes from Sardinia / Corsica on one side and Sicily on the other side. Without going into the details of the extrapolation method, a summary of results is reported here (see **Table 6.7**):

Table 6.7. Estimation of increase in average price and revenues for Cyprus.

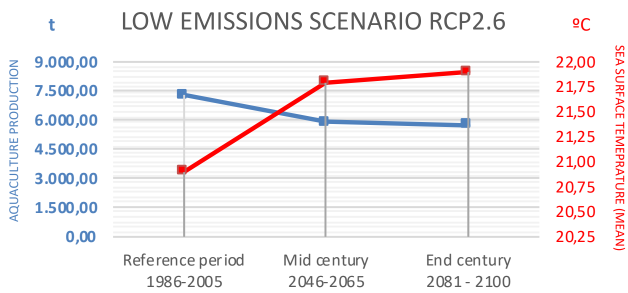
Actual share of days in which Humidex > 35 degrees	Future scenario considered	Days in the corresponding scenario in which Humidex > 35 degrees	Increase in the average price	Increase in the tourism overnight stays	Increase in tourism revenues
50.47%	RCP 2.6 near	61.59%	2.6%	0.5%	3.1%
	RCP 2.6 far	62.47%	2.8%	0.6%	3.4%
	RCP 8.5 near	64.88%	3.4%	0.7%	4.1%
	RCP 8.5 far	88.60%	8.9%	1.8%	10.9%

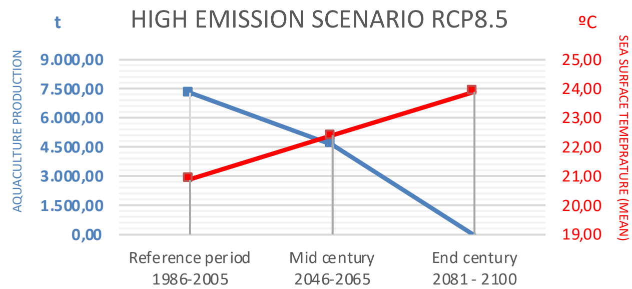
Source: SOCLIMPACT Deliverable Report - D5.3. Data Mining from Big Data Analysis.

According to these findings, the average increase in temperature, which is correlated to a growing thermal stress for tourists, brings an economic advantage to tourism destinations. This is only an apparent contradiction with previous findings. This study does not neglect the fact that if islands are too hot, tourists will choose to move to other (cooler) destinations, that theoretically exist. Then, the increase in tourism (and tourism revenues) stem from the fact that, when the temperature is too hot, people would prefer to move to coastal areas (where the climatic conditions are more bearable) than staying inland or in cities. Future trends will also facilitate this pressure of tourism demand (think about the spreading of smart working activities where, in principle, the worker can relocate wherever he/she wants).

6.5.2. Aquaculture

To do this, we assume two main species cultured in this region: Seabream (SB) and Tuna (T), and a model of production function, calculating the monthly biomass production which depends on the monthly water temperature. Results are presented on yearly base (mean values). In order to facilitate the interpretation of the results, we present the value of production of the last year available, for which we calculate the new values under the different climate change scenarios. As expected, the production levels (tons) will decrease for both, low and high emissions scenarios (see **Figure 6.27**).





7,303.00 *	5.922,73 ▼(-18.9%)	5.732,86 ▼(-21.5%)
20.9	21.8	21.9

PRODUCTION SHARE	%
SEABREAM	34
SEABASS	16
BLUEFIN TUNA	50

7,303.00 *	4,659.31 ▼(-36.2%)	0 ▼(-100%)
20.9	22.40	23.90

Figure 6.27. Estimations of changes in aquaculture production (tons), due to increased sea surface temperature.

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

6.5.3. Energy

Climate change may impose welfare reductions to the European islands' societies by affecting thermal comfort. Cooling Degree Days (CDD) are a measure of how much (in degrees), and for how long (in days), outdoor air temperature is higher than 21 °C. The CDD is used as a measure of the energy needed to cool buildings. The increase in CDD and the energy demand (GWh/year) for cooling are estimated for the islands, under different scenarios of global climate change.

Under the high emissions scenario, it is expected that the CDD increase to 1183 CDD aprox in 2100. Under this situation, the increase in cooling energy demand is expected to be 252 % (see **Figure 6.28**).

The Standardized Precipitation Evapotranspiration Index (SPEI) is analysed as a representative indicator for increases in water demand for islands' residents, tourists and agriculture, while it also provides an indication on the available water stored in dams or underground resources. To estimate the increase of energy demand due to the increase in water demand, it was assumed that most of the islands will have to produce desalinated seawater (or groundwater) to meet further increases of demand. Thus, the estimation of the increase in energy demand (GWh/year**)** to produce more drinking water has been done based on the energy consumption required to desalinate seawater.

Under the low emissions scenario (RCP2.6), there are not significant changes in the SPEI indicator, that will remain in its "normal" level, as it is nowadays. Nevertheless, an increase of 36 % in desalination energy demand is expected. Under RCP8.2, the scenario alerts on a severe aridity leading to an increase of 159 % of the energy demand (see **Figure 6.29**).

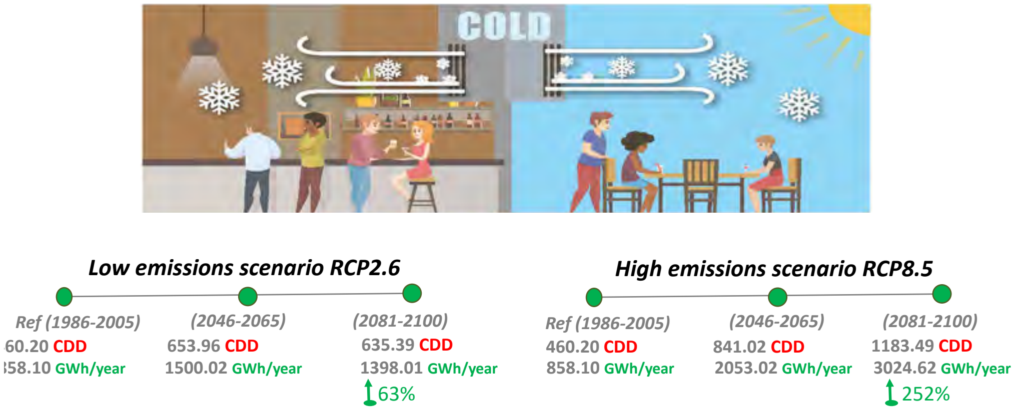


Figure 6.28. Estimations of increased energy demand for cooling in Cyprus under different scenarios of climate change until 2100.

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

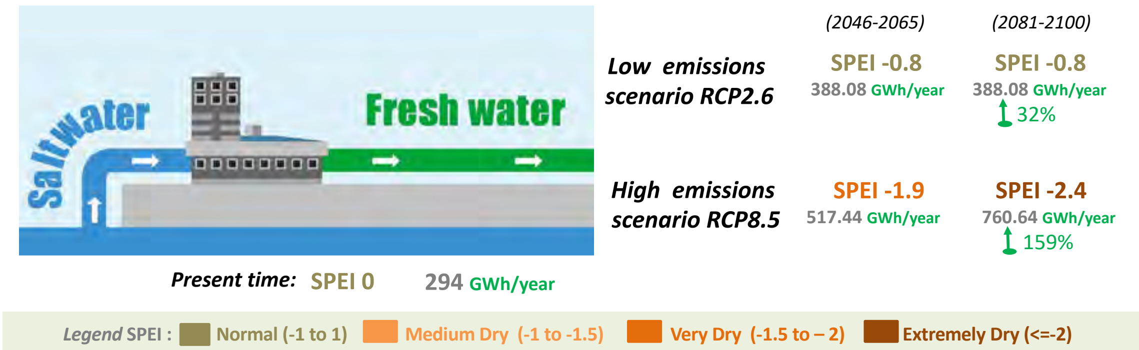


Figure 6.29. Estimations of increased energy demand for desalination in Cyprus under different scenarios of climate change until 2100.

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

6.5.4. Maritime Transport

For maritime transport, it has been estimated the impact of Sea Level Rise on ports' operability costs of the island. The costs have been calculated with reference to 1 meter; this is, the investment needed to increase the infrastructures' height by 1 meter. There is not necessarily a strict correspondence between the SLR and the required elevation of port infrastructures, which also depends on the coastal hydrodynamic and the shape of dikes of each port. By experts' recommendation, we have assumed that 1 meter increase in port height is required to cope with the SLR under RCP 8.5 scenario of emissions. Extrapolation for other RCP scenarios is then conducted based on proportionality.

The starting point was the identification of the principal ports in each island (economic relevance). Second, the analysis of the different port areas (exterior, ramps, oil, etc.), and their uses. Third, the elevation costs were estimated per each area and port separately (considering 1 meter elevation). Thus, the costs of 1 meter elevation presented are the sum of all areas and ports analysed and including the rest of the ports of the island (if applicable) based on proportionality. Estimations consider that all ports areas of the entire area should be elevated at the same time. In other words, the economic values can be interpreted as the depreciation (amortization) costs of the investment needed to increase all port infrastructures on the island within the next 125 years. No discount rate has been applied.

As expected, the rising of sea levels will affect the sector, as new investment will be needed to keep ports' operability. Under the high emissions scenario, it is expected that these costs could increase 4.3 million euros per year until the end of the century (see **Figure 6.30**).

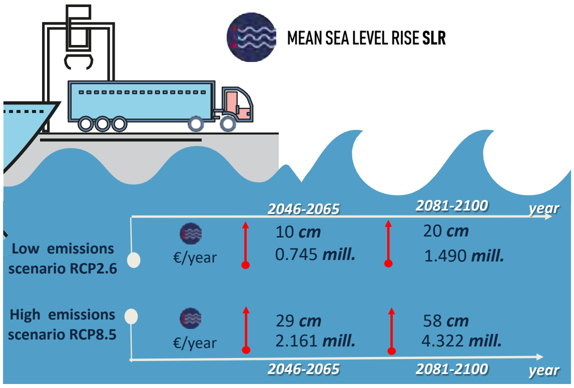


Figure 6.30. Increased costs for maintaining ports' operability in Cyprus under different scenarios of SLR caused by climate change until 2100.

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

6.6. Impacts on the Island's Socio-Economic System

The aim of our study is to assess the socioeconomic impacts of biophysical changes for the island of Cyprus. For this purpose, we have used the GEM-E3-ISL model, a single-region, multi-sectoral general equilibrium model based on the principles of neo-classical theory, and GINFORS, a macro-econometric model based on the principles of post-Keynesian theory.

Both models include 14 sectors of economic activity, with an emphasis on services and specifically on those composing the tourism industry. The GEM-E3-ISL model also includes endogenous representation of labor and capital markets as well as bilateral trade flows by sector.

Changes in the mean temperature, sea level and precipitation rates are expected to affect energy consumption, tourism flows and infrastructure developments. These impact-chains have been examined and quantified under two emission pathways: RCP2.6, which is compatible with a temperature increase well below 2 °C by the end of the century, and RCP8.5, which is a high-emission scenario. The impact on these three factors was used as input in the economic models, which then assess the effects on GDP, consumption, investments, employment, etc.

In total 17, scenarios have been quantified for Cyprus. The scenarios can be classified in the following categories:

1. Tourism scenarios: these scenarios examine the reduction in tourism revenues due to changes in human comfort as captured by the hum-index, the degradation of marine environment, the increased risk of forest fires and beach reduction. The aggregate tourism scenario (TOUR-SC6) assesses the economic impacts of a simultaneous change of all (the above-mentioned) factors.
2. Energy scenarios: the aggregate energy scenario (ENER-SC3) assessed the impacts on regional economic performance of increased total electricity demand driven by cooling and water desalination demand.
3. Infrastructure scenario: this scenario assesses the impact of port infrastructure damages (INFRA-MAR).
4. Aggregate scenarios: these scenarios examine the total impact of the previously described changes in the economy.

In the aggregate scenario, we examine the impacts of a simultaneous change in electricity consumption, tourism revenues and infrastructure damages. The scenario specifications for the two climatic variants are presented below (see **Table 6.8**):

Table 6.8. Aggregate scenario –inputs.

	Tourism revenues (% change from reference levels)	Electricity consumption (% change from reference levels)	Infrastructure damages (% of GDP)
RCP2.6 (2045-2060)	-10.88	19.30	-0.02
RCP2.6 (2080-2100)	-14.83	16.60	-0.02
RCP8.5 (2045-2060)	-41.33	37.00	-0.06
RCP8.5 (2080-2100)	-49.24	68.60	-0.07

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

The theoretical and structural differences of the two models mean that this study produces a reasonable range of impacts, given the uncertainty embodied in economic analysis and especially in the long-term.

In GEM-E3-ISL, the economy is in equilibrium at each point in time. Prices adjust to ensure that supply equals demand (market clearing) and capital is fully used. However, the model allows for equilibrium unemployment as it takes into account labor market rigidities. The impacts are driven mainly by the supply side through changes in production costs which influence relative prices; hence, competitiveness and trigger substitution effects. The GEM-E3-ISL model assesses the impacts on the economy up to 2100.

The macro-econometric type of models, such as GINFORS, do not require that all markets are in equilibrium; idle capital and involuntary unemployment are some other features of this type of models where the results are driven mainly by adjustments in the demand side of the economy. The GINFORS assesses the impacts on the economy up to 2050.

With respect to GDP, the estimated change compared to the reference case is between -0.95% and -2.2% in the RCP2.6 in 2050 and between -4.0% and -8.0% in the RCP8.5. The cumulative change over the period 2040-2100 is estimated (by GEM-E3-ISL) to be equal to -1% in the RCP2.6 and -4% in the RCP8.5. In GEM-E3-ISL, the GDP impacts are driven almost equally by the energy and the tourism component in both climatic variants examined (see **Figure 6.31**).

With respect to sectoral impacts, both models show a significant decrease in the activity of tourism related sectors and an increase in the activity of the manufacturing sector and to a lesser extent in the consumer goods industries sector. In the GEM-E3-ISL, model the reduction in wages in response to the increasing unemployment in the tourism industries

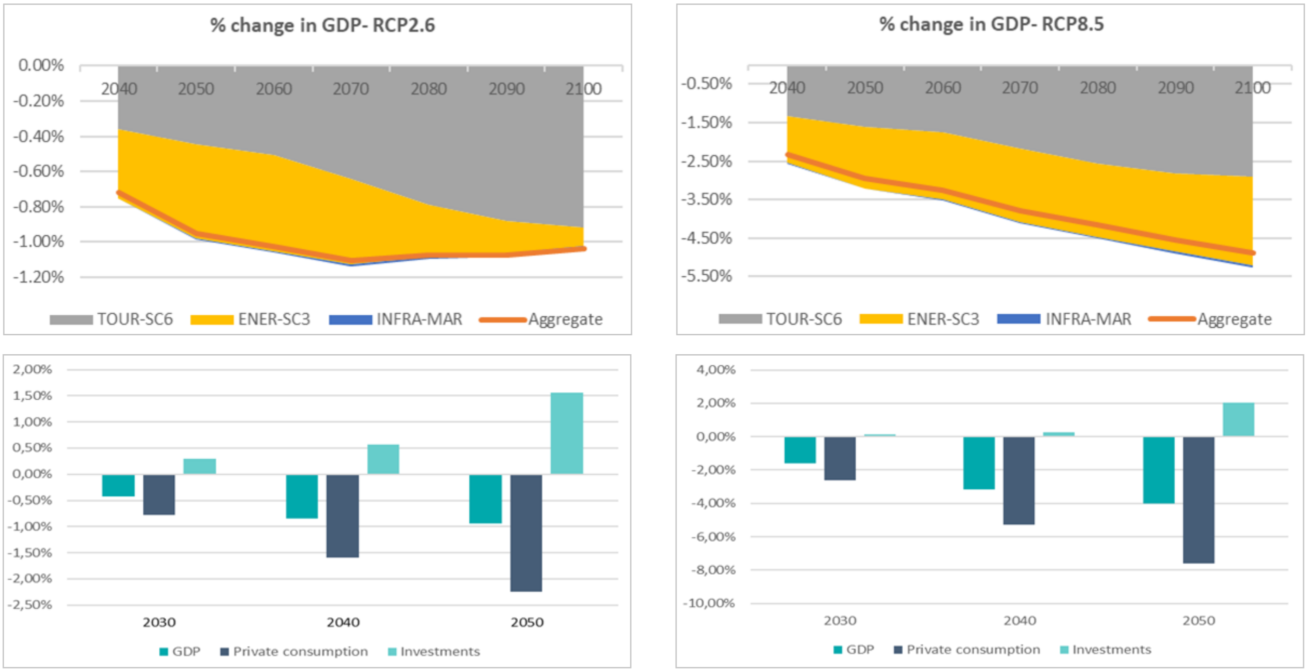


Figure 6.31. Percentage change in GDP. GEM-E3-ISL results (above), GINFORS (below).
Source: own calculation.

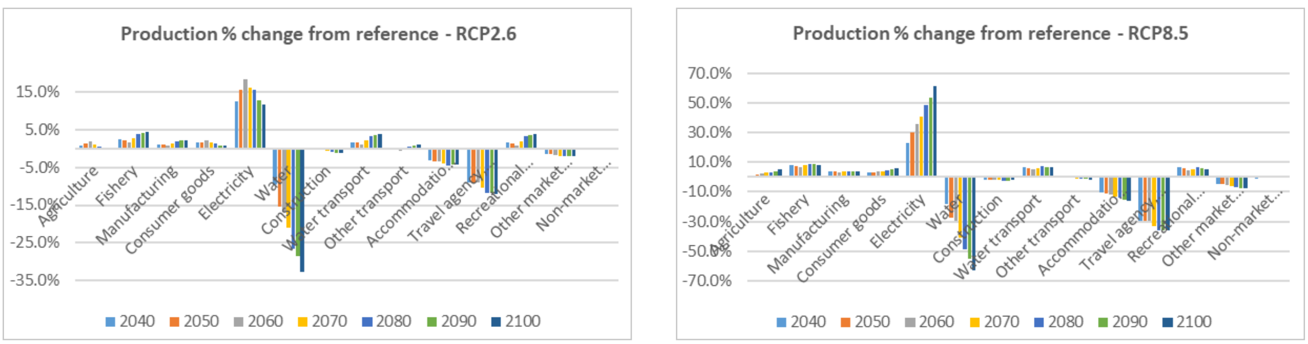


Figure 6.32. Production percentage change from reference. GEM-E3-ISL results.
Source: own calculation. *(Continued on the next page)*

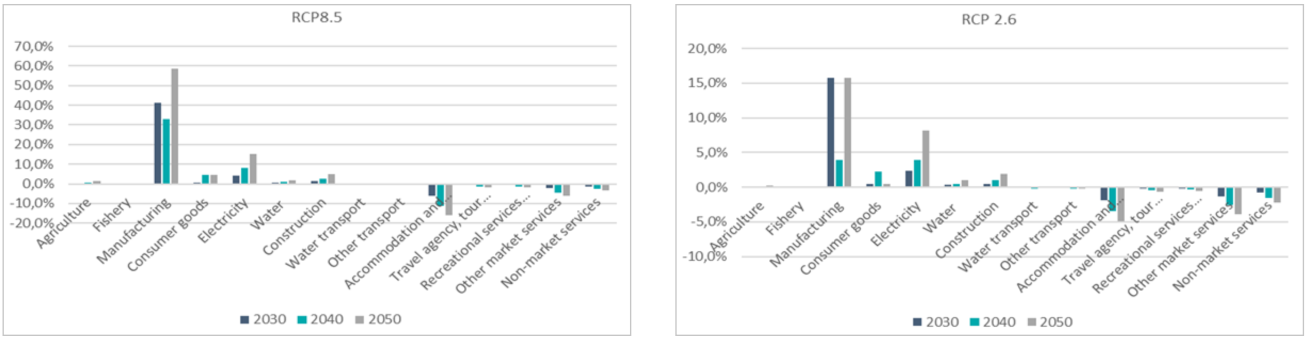


Figure 6.32 (Cont.). Production percentage change from reference. GINFORS results.
Source: own calculation.

implies competitiveness gains for other market services (e.g., business sector, trade etc.) (see **Figure 6.32**).

Overall, employment falls in the economy and especially in tourism related sectors following the reduction in tourist influx. Increased investments to expand the electricity generation capacity within the island are expected to positively influence employment, while the primary and secondary sectios benefit from the lower wages in the economy; hence jobs increase in these sectors as production becomes (relatively) more labor intensive, and the overall activity of the sectors increase due to competitiveness gains (which lead to higher demand both in domestic and in international markets). Employment falls on average by 0.3% in the RCP2.6 and by 0.9% in the RCP8.5 (see **Figure 6.33**).

Figure 6.33. Employment percentage change from reference . GEM-E3-ISL results (above), GINFORS (below).
Source: own calculation.

6.7. Towards Climate Resiliency

The island has adopted a number of climate change actions at both national and European level. The following list comprises the most important actions:

- 1992:
  Adoption of the United Nations Convention on Climate Change (UNFCCC) to stabilize concentrations of greenhouse gases in the atmosphere at levels that prevent dangerous impacts on the climate from human activities.
- 1994:
  UNFCCC entered into force.
- 1997:
  Cyprus ratified the UNFCCC as a non-Annex I Party.
- 1998:
  Adoption of the Kyoto Protocol to limit greenhouse gas emissions for the periods 2008-2012 and 2013-2020.
- 2003:
  Cyprus ratified the Kyoto Protocol.
- 2008:
  Start of the Kyoto Protocol's First Commitment period.
- 2009:
  EU's Climate and Energy Package for 2020 agreed.
- 2011:
  Cyprus changed its UNFCCC status to Annex I Party.
- 2011:
  EU's 2050 Roadmap agreed.
- 2012:
  End of the Kyoto Protocol's First Commitment period.
- 2012:
  Doha amendment to the Kyoto Protocol for 2013-2020.
- 2015:
  Adoption of the Paris Agreement to reduce greenhouse gas emissions.
- 2016:
  Paris Agreement entered into force.
- 2017:
  Cyprus ratified the Paris Agreement.

With regards to its policies, the Cyprus government has drafted several plans and strategies concerning water, energy and waste into various directives.

- Cyprus Climate Change Risk Assessment (2014).
- National Plan for the Adaptation to Climate Change (2016).
- National Strategy for the Adaptation to Climate Change (2017).
- The River Basin Management Plan and Water Policy drafted in the framework of the Water Framework Directive.
- The Flood Risk Management Plan drafted in the Floods Directive.
- The National energy efficiency action plan of Cyprus drafted in the framework of the Energy Efficiency Directive.
- The National Renewable Energy Action Plan drafted in the framework of the 2009/28/EC Directive.
- The Nearly Zero Energy Buildings Action Plan drafted in the framework of the Energy Performance of Building Directive.
- The European Common Agriculture Policy.
- The National Biodiversity Strategy. Cyprus has formulated the National Biodiversity Strategy (NBS) during 2013, as a reference document in order to fulfil the commitments accepted with the ratification of the Convention on Biological Diversity.
- The Strategy for the Management of waste.
- The low-carbon development strategy of Cyprus to 2050.
- The Multiannual national plan for the development of sustainable aquaculture.

The Ministry of Agriculture, Rural Development and Environment compiled a strategic plan of objectives and actions for the purpose of promoting a green economy, sustainable agriculture and fisheries growth and efficient use of natural resources. Table 6.8 provides a list of these goals (see **Table 6.9**).

Specific limits and obstacles

Stakeholders in the island ratified the existence of important limitations in the fighting against climate change:

- A dedicated process is in place to facilitate stakeholders' involvement in the preparation of adaptation policies. However, there is little (mainly sectoral) evidence of transboundary cooperation to address common challenges with relevant neighbouring countries (cooperation between Mediterranean countries).
- There is a lack of organizations that are responsible for observing the impacts of climate change in various sectors (and monitoring of environmental variables).
- Climate risks/vulnerability assessments do not take transboundary risks into account, when relevant. It is unclear how Cyprus will address climate risks transcending the country's frontiers (e.g., risks coming from warmer countries, changes in the Mediterranean, etc.)
- It is unclear how knowledge gaps are used to prioritize funding in the field of adaptation research. Some research into the assessment of existing and future impacts on vulnerable economic sectors is being financed and carried out through one-off projects. It has been decided to assess all knowledge gaps related to climate change impacts and adaptation and identify possible sources of funding for their research.

Table 6.9. Cyprus strategic goals and objectives.

STRATEGIC PLAN OBJECTIVES & ACTIONS
Climate Change mitigation and adaptation (Department of Environment)
1. Reduction in greenhouse gas emissions and adaptation to climate change. 2. Implementation of international and EU commitments on climate change, protection of the ozone layer and regulation and monitoring of fluorinated greenhouse gases. 3. Coordination of climate change policy issues.
Environmental protection (Department of Environment)
1. Protection of the environment from the activities of industrial and livestock installations, waste management operators and waste producers. 2. Managing species and habitats with the objective of halting the degradation of the conservation status. 3. Assessment of the impacts on the environment from plans/programmes/projects and other actions.
Efficient protection of forests against fires and other agents (Department of Forests)
1. Protection of forests against forest fires. 2. Protection of forests against other agents.
Protection of biodiversity and other ecosystem services (Department of Forests)
1. Protection of biodiversity and other ecosystem services. 2. Adaptation of forests to climate change and contribution of forests to mitigating climate change.
Safeguard the quality and protect the water resources and aquatic environment (Water Development Department)
1. Implementation of the Floods Directive 2007/60/EC.
Protection and conservation of the marine environment (Department of Fisheries and Marine Research)
1. Studies and monitoring of the marine waters up to the EEZ, under the relevant European legislation and International Conventions. 2. Management and Monitoring of Marine Protected Areas. 3. Inspection and combat of oil pollution (combat teams).

Source: SOCLIMPACT Deliverable Report D7.1. Conceptuak Framework.

- Education materials or specific training activities to build adaptation capacity or to help stakeholders to adapt to climate change are not yet available.
- There are no updated sources of information available on climate change data and adaptation policy developments. Cyprus developed a CYPADAPT portal to support the dissemination of information on climate change adaptation. The platform was expected to provide access and share information and views on many different issues concerning adaptation options, climate impacts, vulnerability, case studies, research activities, legislation, financing opportunities, tools for adaptation planning and useful links, but has not been updated since 2014.
- Very few mechanisms are in place to coordinate disaster risk management and climate change adaptation. Disaster Risk Reduction plans do not factor in projected climate extremes that may occur in the future, while the national adaptation strategy does not mention specific disaster preparedness plans or how these account for climate change adaptation.
- Funding is available to increase climate resilience in vulnerable sectors and for cross-cutting adaptation action, but other elements, such as coordination, governance, capacity building, indicators and projections do not have specific allocation of resources. Also, costs of climate change impacts and costs/benefits of adaptation in general have yet to be identified. In order to adopt the measures stated in the National Strategy (2016), a very large number of studies need to be carried out according to the Second Progress Report (2018). These include, among others, studies for (1) the sustainable use of land, (2) the investigation of climate change vulnerable coastal areas, (3) the increase in SLR and effects to current/new coastal structures, (4) the promotion of research regarding biodiversity and climate change.
- The Cypriot authorities just started harmonizing national legislation and mainstream adaptation to reflect on the Environmental Impact Assessment (EIA) Directive.
- Key land use, spatial planning, urban planning and maritime spatial planning policies do not consider the impacts of climate change.

6.7.1. Policy Recommendations

A stakeholders consultation process was carried out in the island, aiming to propose, analyse and rank alternative adaptation measures for the island. The profile of the individuals participating in these focal groups involved policy and decision-makers, practitioners, non-governmental and civil society organisations, science experts, private sector, business operators and sector regulators at island level.

The main aim of these meetings was:

1. Identify and present the characterized packages of adaptation and risk management options for the island.
2. Develop detailed integrated adaptation pathways, in three timeframes: Short term (up to 2030), Mid-century (up to 2050) and End-century (up to 2100).

3. Evaluate and rank adaptation options for 2 blue economy sectors in the island (energy, and tourism).

To this aim, stakeholders utilized five evaluation criteria to rank the proposed measures:

- Cost efficiency: Ability to efficiently address current or future climate hazards/risks in the most economical way.
- Environmental protection: Ability to protect the environment, now and in the future.
- Mitigation win-wins and trade-offs: Current ability to meet (win-win) or not (trade-off) the island / archipelagos mitigation objectives.
- Technical applicability: Current ability to technically implement the measure in the island.
- Social acceptability: Current social acceptability of the measure in the island.

Four scenarios of intervention were analysed, called Adaptation Policy Trajectories, which are different visions of future policy adaptation choices:

- APT A Minimum Intervention - Low investment, low commitment to policy change.
- APT B Economic Capacity Expansion - High investment, low commitment to policy change.
- APT C Efficiency Enhancement - Medium investment, medium commitment to policy change.
- APT D System Restructuring - High investment, high commitment to policy change.

It was assumed that adapting to climate change may range from minimal to high cost, and from requiring a small or incremental change to a significant transformation from the *status quo*. However, not all APT scenarios were considered in all islands, especially when their stakeholders had a clear vision on the types of measures with greatest viability. Therefore, the final set of proposed adaptation measures are framed in the islands' socio-economic and political context, have a sectoral perspective, and respond to the islands' future scenarios of climate change. At the same time, the involvement of regional stakeholders in policy design allows them to engage in the effective implementation of climate actions on their island.

In Appendices from K to N, a brief explanation of each adaptation option can be found, classified by type or class: Vulnerability Reduction, Disaster Risk Reduction, Social-Ecological Resilience, and Local Knowledge. The latest group refers to very specific measures proposed by stakeholders in each island to ratify the needs.

6.7.1.1. Tourism

For the case of APT A, Vulnerability Reduction is achieved by implementing programmes to raise public awareness in the short-term, though the diversification of tourist activities and products are deemed necessary in the mid- and long-term to combat the issue of seasonality that is heavily observed on the island. Measures for Disaster Risk Reduction are almost identical for all three timeframes of APT A. Specifically, drought and water conservation plans are recommended in this APT as it is considered a more feasible and cost-efficient option for managing long term risk, particularly as Cyprus will face an increase in temperature. Similarly, pre-disaster early recovery planning is preferred to deal with Post-disaster recovery and rehabilitation. The reason being that proactive measures (such as best practices and knowledge bases) rather than reactive measures will be less costly and more environmentally protective, thus safekeeping the attractiveness of Cyprus as a tourist destination. With regards to response adaptation, the short-term option of fire management plans is generally beneficial for the island given the FWI projections. However, the mid-term and long-term measures should focus on reinforcing and improving the healthcare delivery system to deal with the possible increase in heatstroke episodes that the risk of rise in temperature will cause. Finally, for satisfying the social-ecological resilience objective, stakeholders opted for monitoring, modelling, and forecasting systems as the measure for provisioning services for all three timeframes. It is deemed necessary that reliable and timely climate information and the ability to assess climate hazard impacts under this APT (low commitment and low investment) would be more suitable for mitigating GHG emissions, as well as a more technically applicable and socially acceptable measure.

For the case of APT B, Vulnerability Reduction consists of financial capital measures throughout the three timeframes given that high investment is a characteristic of this APT. This is due to climate hazard projections indicating that risks will be continually increasing. Also, financial incentives to retreat from high-risk areas is not considered to be as a socially accepted or technically applicable measure. The implementation of public awareness programmes is a desired measure for the short-term, whereas activity and product diversification is more suitable for the mid- and long-term. Again, it is important to deal with the issue of seasonality but also to be in line with commitments to the Paris Agreement and EU directives. The only class of adaptation for Disaster Risk Reduction involves managing long-term risks. Here, the short- and mid-term option selected for this APT (low commitment, high investment) is the construction of coastal protection structures, mainly because the SLR and wind wave projections indicate extensive beach reduction at coastal areas, which in turn would decrease the attractiveness of the island as a tourist destination. For the long-term, the development of drought and water conservation plans is the most appropriate measure, again, based on the increase in mean daily temperature on the island. Regarding social-ecological resilience, provisioning services and regulating and maintenance services are the two adaptation classes involved. For adaptation via provisioning services, monitoring, modelling, and forecasting systems were chosen as the measure for all three timeframes. For adaptation via regulating and maintenance services, the measure chosen was dune restoration and rehabilitation for all three timeframes. In addition, for the long-term, the pathway also includes the measure for river rehabilitation and restoration given that in the future there will be both higher temperatures and water demand. Hence, this measure will increase available leisure areas for improved thermal comfort and increase water availability.

For the case of APT C, Disaster Risk Reduction is achieved through managing long-term term risk and preparedness. The most appropriate measure for managing long-term risk was chosen to be the construction of coastal protection structures up until 2030, whereas the development of drought and water conservation plans were chosen as the most suitable up until both 2050 and 2100. This is similar to the choices for APT B, with the only difference being the mid-term measure. Since APT C has medium commitment and medium investment (as opposed to high investment in APT B), the construction of coastal protection structures is considered a more costly adaptation measure. Adaptation via preparedness contains the measure using water to cope with heat waves for all three timeframes. Additionally, for the mid-term, mainstreaming disaster risk management is also included in this pathway. Moreover, the mid- and long-term also include the measure for river rehabilitation and restoration based on the forecasts for temperature and water demand (both increasing). Finally, for cultural services adaptation, the preferred measure is adaptive management of natural habitats in order to deal with the impacts and pressures of human activities on the island's biodiversity and ecosystems that are aggravated by climate change. This measure is more relevant based on the projections for hazards like fire weather index, seagrass evolution, and beach reduction.

For APT D, Vulnerability Reduction it is proposed the implementation of economic policy instruments since it is technically easier to apply and considered to be more socially acceptable. Furthermore, this specific APT assumes high investment and high commitment, therefore, the measure is also cost-effective. Stakeholders also suggest improving the activity and product diversification of the island for all three timeframes. Since there will be high commitment to policy change, as well as more investment, this measure is more suitable to deal with seasonality, infrastructure overload, and the burden on ecosystems that the tourism industry faces. Water restrictions, consumption cuts, and grey-water recycling is considered a more appropriate measure for the short-term since it will be necessary to deal with the increase in temperature and water demand. However, the mid- and long-term will benefit from measures promoting local sustainable fishing. The restructuring of the system will protect ecosystem services and decrease external dependency. Adaptations to deal with Disaster Risk Reduction concern managing long-term risks and Post-disaster recovery and rehabilitation. For the former, the construction of coastal protection structures will serve the island better in short-term, as there will be a need to protect the coast from beach reduction. If this is taken care of, then focus can shift towards development of drought and water conservation plans in the mid- and long-term to combat the problem of rising temperatures and water demand in the future. For the latter, just as in APT A, Post-disaster early recovery planning is the most appropriate measure for the same reasons – maintaining Cyprus as an attractive tourist destination. With respect to social-ecological resilience, provisioning services is the only contributing class of adaptation. Here, for the short- and mid-term, it is preferred to invest in the development of monitoring, modelling, and forecasting systems, so that accurate climate data is obtained as fast as possible. However, in the long-term, a measure for adaptation of groundwater management will offer better environmental protection (see **Table 6.10**).

Table 6.10. Proposed adaptation options for tourism in Cyprus.

<table>
<tr><td rowspan="6">APT A – Pathway
—
Minimum Intervention
low investment, low commitment to policy change
—
This policy trajectory assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td colspan="2">Public awareness programmes</td><td>Activity and product diversification</td></tr>
<tr><td colspan="3">Drought and water conservation plans</td></tr>
<tr><td>Fire management plans</td><td colspan="2">Health care delivery systems</td></tr>
<tr><td colspan="3">Pre-disaster early recovery planning</td></tr>
<tr><td colspan="3">Monitoring, modelling and forecasting systems</td></tr>
<tr><td rowspan="7">APT B – Pathway
—
Economic Capacity Expansion
high investment, low commitment to policy change
—
This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td colspan="3">Economic Policy Instruments (EPIs)</td></tr>
<tr><td>Public awareness programmes</td><td colspan="2">Activity and product diversification</td></tr>
<tr><td colspan="2">Beach nourishment</td><td>Desalination</td></tr>
<tr><td colspan="2">Coastal protection structures</td><td>Drought and water conservation plans</td></tr>
<tr><td colspan="3">Monitoring, modelling and forecasting systems</td></tr>
<tr><td colspan="2">Dune restoration and rehabilitation</td><td>River rehabilitation and restoration</td></tr>
</table>

Table 6.10 (Cont.). Proposed adaptation options for tourism in Cyprus.

<table>
<tr><td rowspan="9">APT C – Pathway
—
Efficiency Enhancement
medium investment, medium commitment to policy change
—
This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td>Public awareness programmes</td><td colspan="2">Activity and product diversification</td></tr>
<tr><td>Tourist awareness campaigns</td><td colspan="2">Local circular economy</td></tr>
<tr><td colspan="3">Water restrictions, consumption cuts and grey-water recycling</td></tr>
<tr><td>Coastal protection structures</td><td colspan="2">Drought and water conservation plans</td></tr>
<tr><td>Using water to cope with heat waves</td><td>Mainstreaming Disaster Risk Management</td><td>Using water to cope with heat waves</td></tr>
<tr><td colspan="3">Monitoring, modelling and forecasting systems</td></tr>
<tr><td colspan="2">Dune restoration and rehabilitation</td><td>River rehabilitation and restoration</td></tr>
<tr><td colspan="3">Adaptive management of natural habitats</td></tr>
<tr><td rowspan="8">APT D – Pathway
—
System Restructuring
high investment, high commitment to policy change
—
This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td colspan="3">Economic Policy Instruments (EPIs)</td></tr>
<tr><td colspan="3">Activity and product diversification</td></tr>
<tr><td>Water restrictions, consumption cuts and grey-water recycling</td><td colspan="2">Local sustainable fishing</td></tr>
<tr><td>Coastal protection structures</td><td colspan="2">Drought and water conservation plans</td></tr>
<tr><td colspan="3">Pre-disaster early recovery planning</td></tr>
<tr><td colspan="2">Monitoring, modelling and forecasting systems</td><td>Adaptation of groundwater management</td></tr>
</table>

Vulnerability Reduction · *Disaster Risk Reduction* · *Socio-Ecological Resilience* · *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

6.7.1.2. Energy

For the case of APT A, Vulnerability Reduction is attained by promoting green jobs and businesses in all timeframes. This is because they can provide multiple benefits regarding sustainable development but also for combating the current COVID-19 pandemic. Additionally, in the short-term, the provision of a public information service on climate action is also a recommended measure, as it could yield immediate results for supporting residential, hotels and commercial buildings to adapt to climate change. Disaster Risk Reduction for this APT is achieved by focusing on managing long-term risk, response, and Post-disaster recovery and rehabilitation. For managing long-term risk, stakeholders deemed the inclusion of both available options as critical for all three timeframes. The review of building codes of the energy infrastructure for Cyprus is an ongoing process that is necessary for protecting the environment and mitigating GHG emissions.

On the other hand, the upgrading for the evaporative cooling systems is considered necessary until the end of the century given that water scarcity and heat waves are hazards that will severely impact the island. Hence, the technology to deal with this will need continuous improving over time. With respect to disaster response, being able to locally produce energy has both cost and environmental benefits, and therefore, a measure for constructing energy-independent facilities (generators) is included for all timeframes. Also, the study and development of energy grid connections between islands is recommended in the short-term (contributing towards the increase of renewable energy resources (RES) and in the long-term (for the purpose of improving the reliability of the energy system). The preferred measure for adaptation via Post-disaster recovery and rehabilitation is the operation of energy recovery microgrids for all three timeframes. This measure benefits the local generation of energy and reduces costs, which is in line with the characteristics of this pathway trajectory (low commitment and low investment). In the short-term, increasing and improving the capacity of the island to recover from energy outages are also important based on the exacerbation of climate events projected.

For the case of APT B, Vulnerability Reduction concerns financial support for buildings with low energy needs for the short-term, as this measure contributes towards the protection of the environment. However, for the mid- and long-term, the suggested measure involves financial support for smart control of energy in houses and buildings. This measure will help cut costs and mitigate GHG emissions. Also, promoting green jobs and businesses in all timeframes and, as well as the dissemination of public information service on climate action are considered an immediate measure in the short-term. Furthermore, for all timeframes, the implementation of demand-side management of energy as a strategy for improving the coordination of energy producers and energy consumers is also recommended, since it is more socially acceptable, contributes more, and is a more practical solution in the long-run.

For Disaster Risk Reduction, the option selected here is the review of building codes of the energy infrastructure, since this measure is more technically applicable and cost-efficient in the immediate future and will help climate-proof the energy system of the island. For the mid- and long-term, the option of upgrading evaporative cooling systems is chosen to combat reduced water availability and increasing temperatures. With respect to social-ecological resilience, the two classes of adaptation included in this APT are provisioning services and regulating and maintenance services. For the former, the options selected follow the options selected in APT A. Specifically, energy efficiency of urban water management needs to be addressed in the immediate future, whereas the inclusion of underground tubes and piping in urban planning needs to be addressed in the distant future. For the former, the promotion of biomass power from household waste is the short-term measure recommended, since it is a good GHG emissions mitigating alternative. In the mid- and long-term, however, the construction of urban green corridors is the measure of choice because it will be effective in combating the projected increase in air temperature on the island.

For the case of APT C, short- and mid-term measures consist of the promotion of green jobs and businesses, as well as of the provision of as public information service on climate action. The fact that there is medium commitment to policy change and medium investment makes the latter measure also viable for the long-term. It was also proposed the promotion of small-scale production and consumption for all timeframes. This measure will be able to deal with climate change events forecast for the island (particularly, heat waves). The transition to local energy production will have significant benefits on multiple levels and will contribute much more to the usage of RES, the decrease of GHG emissions, and the creation of jobs at the local level. In addition, the mid- and long-term pathways also contain the development of a risk reporting platform as a measure. The development of energy storage systems is recommended for all timeframes, which is in line with the EU's energy policy aiming for increase RES usage.

Furthermore, the collection and storage of forest fuel loads is also included for the mid- and long-term pathways, as a way to deal with highly potential wildfire hazards that are projected for the island. The objective for Disaster Risk Reduction is obtained with reviewing building codes of the energy infrastructure in the short-term and a measure for upgrading evaporative cooling systems in the mid- and long-term. Stakeholders also decided for all timeframes to include a measure to ensure grid reliability, since it is important to upgrade the grid and guarantee it is constantly stable. In the short-term, it is also important to invest in early warning systems, given the various immediate climate hazards. Furthermore, stakeholders suggested that investment in early warning systems in the long-term will also be necessary for the purpose of upgrading based on new knowledge. APT C includes all three classes of adaptation relating to social-ecological resilience. For adaptation via provisioning services, the selection of measures follows APT A and APT B, with the short-term consisting of improving energy efficiency in urban water management and the mid- and long-term consisting of implementing underground tubes and piping in urban planning. Regarding regulating and maintenance services adaptation, promoting the generation of biomass power from household waste is more appropriate for all timeframes, since this APT is characterized by medium investment and medium commitment to policy change. In addition, for the mid- and long-term, the ATP also includes the creation of urban green corridors. Finally, for cultural services, the short-term measure more suitable for this APT is the provision of educational garden plots.

For the case of APT D, the inclusion of measures is similar to those included in APT B, with providing financial support for smart control of energy in houses and buildings in the mid- and long-term and providing financial support for buildings with low energy needs in the short-term. However, because this APT has a high degree of commitment to policy change (as opposed to a low degree of commitment in APT B), it also includes providing financial support for buildings with low energy needs in the mid- and long-term. The measures selected by stakeholders is exactly as in the case of APT C. The development of energy storage systems is preferred for all timeframes, whereas the collection and storage of forest fuel loads is also selected for the mid- and long-term pathways. Disaster Risk Reduction objectives are met through managing long-term risks and Post-disaster recovery and rehabilitation. For the former, again this pathway consists of measures identical to that of APT C – the short-term involves reviewing building codes of the energy infrastructure, whereas the mid- and long-term involve upgrading evaporative cooling systems. For the latter, the operation of energy recovery microgrids is recommended for all three timeframes (as in APT A), however, as this APT has a high level of investment, it is also recommended that the mid- and long-term also includes increasing and improving the capacity of the island to recover from energy outages. Regarding social-ecological resilience objectives, the selection of measures is the same as the other three APTs. Specifically, the short-term measure of improving the energy efficiency of urban water management is preferred, whereas the inclusion of underground tubes and piping in urban planning is suggested for the mid- and long-term (see **Table 6.11**).

Table 6.11. Proposed adaptation options for the energy sector in Cyprus.

APT A – Pathway	Short-term (up to 2030)	Mid-century (up to 2050)	End-of-century (up to 2100)
— **Minimum Intervention** low investment, low commitment to policy change — This policy trajectory assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts	Public information service on climate action	Green jobs and businesses	
	Review building codes of the energy infrastructure		Upgrade evaporative cooling systems
	Study and develop energy grid connections	Energy-independent facilities (generators)	
	Local recovery energy outage capacity	Energy recovery microgrids	
	Energy efficiency in urban water management	Underground tubes and piping in urban planning	

Table 6.11. Proposed adaptation options for the energy sector in Cyprus.

APT B – Pathway — **Economic Capacity Expansion** high investment, low commitment to policy change — This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy	**Short-term (up to 2030)**	**Mid-century (up to 2050)**	**End-of-century (up to 2100)**
	Financial support for buildings with low energy needs		
	Public information service on climate action	Green job and businesses	
	Seawater Air Conditioning (SWAC)	Demand Side Management (DSM) of Energy	
	Review building codes of the energy infrastructure		Upgrade evaporative cooling systems
	Energy efficiency in urban water management	Underground tubes and piping in urban planning	
	Biomass power from household waste	Urban green orridors	

APT C – Pathway — **Efficiency Enhancement** medium investment, medium commitment to policy change — This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system	**Short-term (up to 2030)**	**Mid-century (up to 2050)**	**End-of-century (up to 2100)**
	Green jobs and businesses	Public information service on climate action	
	Small scale production and consumption (prosumers)		Risk reporting platform
	Energy storage systems		Collection and storage of forest fuel loads
	Review building codes of the energy infrastructure	Upgrade evaporative cooling systems	
	Early Warning Systems (EWS)	Grid reliability	Early Warning Systems (EWS)
	Energy efficiency in urban water management	Underground tubes and piping in urban planning	
	Biomass power from household waste		Urban green corridors
	Educational garden plots	Heated pools with waste heat from power plant	

APT D – Pathway — **System Restructuring** high investment, high commitment to policy change — This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems	**Short-term (up to 2030)**	**Mid-century (up to 2050)**	**End-of-century (up to 2100)**
	Financial support for buildings with low energy needs		
	Public information service on climate action	Green jobs and businesses	
	Energy storage systems		Collection and storage of forest fuel loads
	Review building codes of the energy infrastructure	Upgrade evaporative ooling systems	
	Energy recovery microgrids		Local recovery energy outage capacity
	Energy efficiency in urban water management	Underground tubes and piping in urban planning	

Vulnerability Reduction — *Disaster Risk Reduction* — *Socio-Ecological Resilience* — *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

Chapter 7

Fehmarn (Germany)

SOCLIMPACT

This project has received funding from
the European Union's Horizon 2020 research
and innovation programme under
Grant Agreement No 776661

CONTENTS

Fehmarn at a Glance

Fehmarn is the third largest German Baltic Sea island with an area of 85.5 km^2 and a population of 12.500 inhabitants. It is located between the Bay of Kiel in the West, and the Bay of Mecklenburg in the East. The island can be reached via a bridge that connects it to the German mainland (train, car, walking), and by boat. There is a ferry port on the island's North side, with regular connections to Denmark several times per day. The island is mostly flat (highest elevation 27.2 m) and has a partially undulating land mass, as well as low dunes, beach lakes, and sand pits at the north coast, and a cliffed coast in the east. With many sandy beaches, it is vulnerable to erosion caused by storm surges. A large fraction of the land is used for intensive agriculture, mostly producing rape seed and cereals.

The Blue Economy Sectors

- **Tourism**

  Tourism is the island's most important source of income. Approximately 300,000 overnight guests stay on Fehmarn every year, with the vast majority being German (~99%). Many tourists stay on one of the huge campsites that are situated at different locations along the coastline. A lot of people use the same caravan pitch for many years or even decades and visit regularly during holidays and on weekends throughout the season. For people from northern German municipalities, Fehmarn is also a popular day trip destination, as the connecting mainland bridge makes the island easily accessible by car.

- **Energy**

  Fehmarn's electricity grid, as well as the water supply, are connected to the German mainland. Particularly, the island's wind parks are economically relevant. The wind turbines produce 443,160 MWh/year, which is approximately equal to 464% of the island's energy demand. Being one of the sunniest regions in Germany, PV plants are also widely used. Together with energy produced via the burning of agricultural biomass, Fehmarn produces and exports far more electrical energy to the mainland than it requires for its own consumption.

- **Maritime Transport**

  Maritime transport does not play an island-typical role as most cars and trains arrive via the Fehmarn Sound Bridge from the German mainland. Most maritime transport is happening at Puttgarden harbour, where the ferry connection to Denmark operates. It forms part of the shortest route between Hamburg and Copenhagen and has been heavily used for centuries. Apart from Puttgarden, maritime traffic in Fehmarn is rather small scale with no remarkable international ship traffic going on. Burgstaaken, the second largest port, serves as the home port for local fishing boats, and for shipping agricultural products to the German mainland. It also has touristic infrastructure with a submarine museum, a marina, and gastronomy.

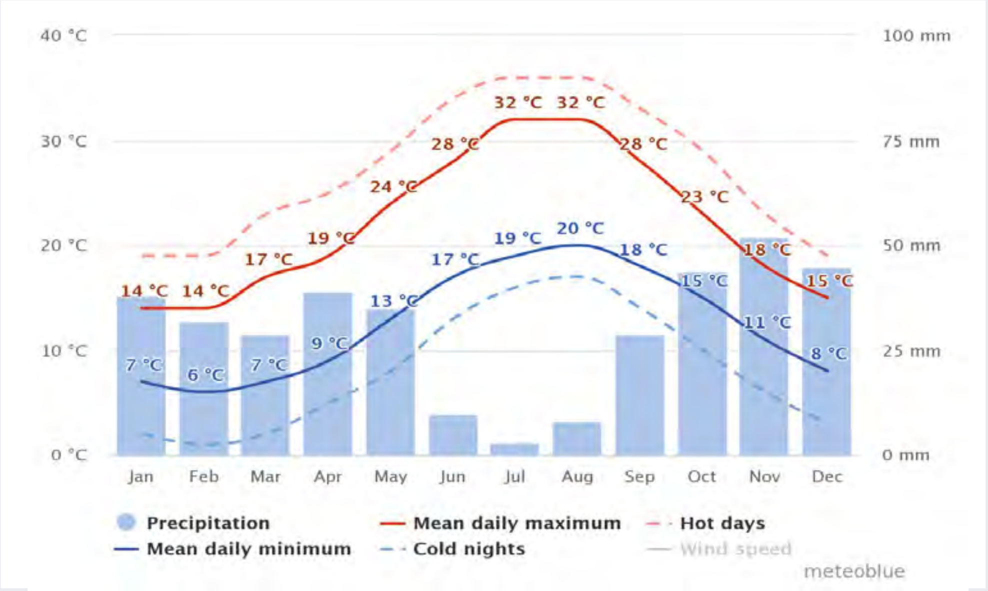
7.1. Current Climate and Risks

At the German Baltic coast, the climate is central European with relatively cool summers and humid winters. Even though the number of sunny days at the coast is higher than further inland and Fehmarn is considered to be the sunniest German island, precipitation are common in all seasons. Westerly winds are predominant and there is no influence of the Gulf Stream on the climate of the Baltic region. As the water exchange between the North Sea and Baltic Sea is small, the salinity of the Baltic Sea is extremely low. As a result of these brackish conditions, large areas of the Baltic Sea can get frozen during some winters.

The cool water of the Baltic Sea is also responsible for relatively low maximum air temperatures along coastal areas in the summer (on average not much higher than 20 °C). During winter, on the other hand, the temperature buffering capacity of the Baltic Sea causes relatively mild average temperatures (rarely dropping below 0 °C) (see **Figure 7.1**). In comparison, air temperatures in areas further inland can get much colder.

CLIMATE CHARACTERISTICS (54.47°N 11.15°E, 4m asl)

Average temperature and precipitation



Wind speed

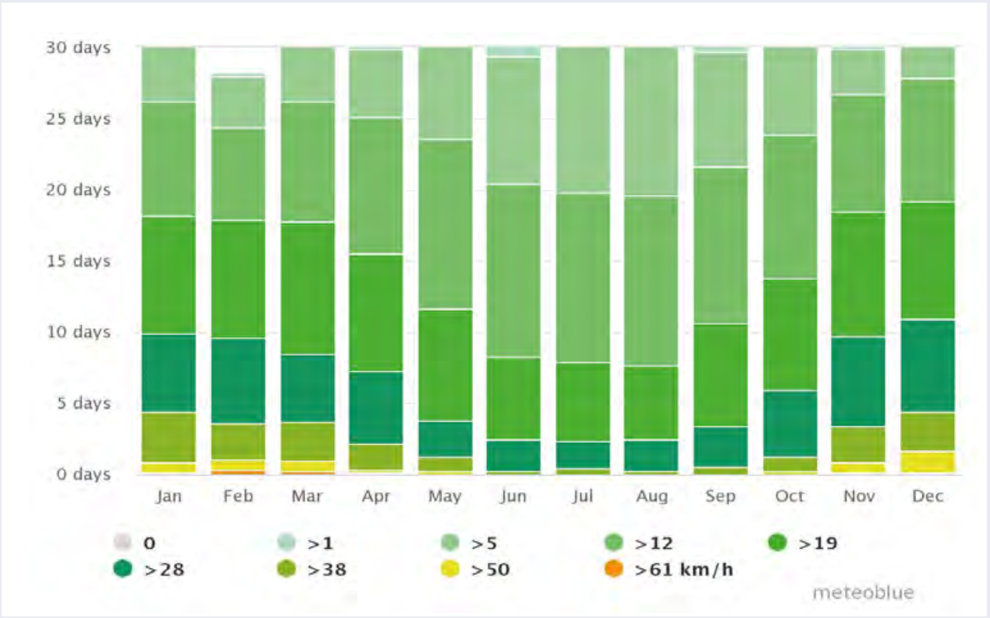
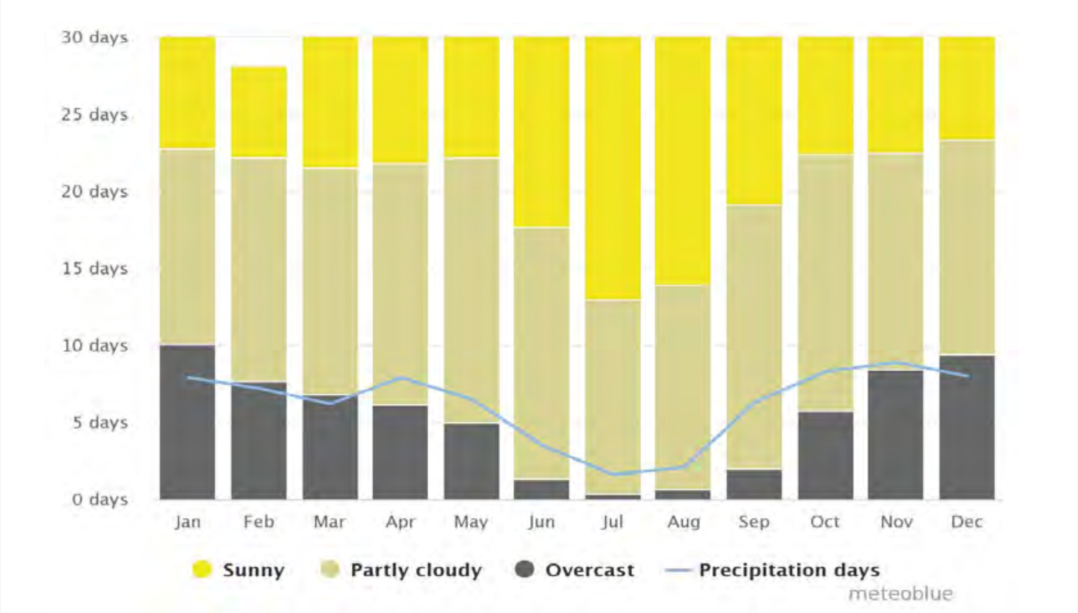


Figure 7.1. Average temperature and precipitation on Fehmarn (figure is part of the Climate factsheet for Fehmarn).

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System). ***(Continued on the next page)***

Cloudy, sunny and precipitation



Wind rose

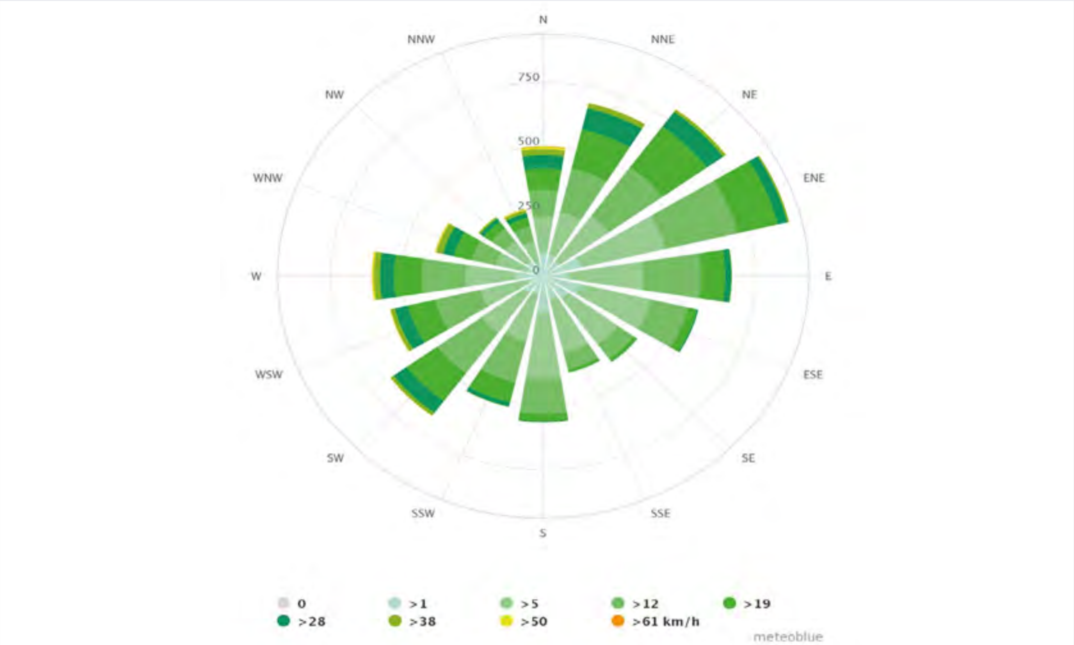


Figure 7.1 (Cont.). Average wind directions and speeds on Fehmarn (figure is part of the Climate factsheet for Fehmarn).

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System).

7.2. Climate Change Outlook

Climate hazard indicators represent the entry point to understand the climate change exposure of blue economy sectors. The indicators have been computed for two scenarios from the IPCC Assessment Report, RCP2.6 (low emission scenario) and RCP8.5 (high emission scenario). In addition, they were calculated for different time horizons within those scenarios, namely: a reference period (1965-2005), mid-century (2046-2065) and end of century (2081-2100). The main source of climate projections for Fehmarn is the EURO-CORDEX ensemble, but other model sources were applied when required, depending on available scales. Results are presented in form of graphs or tables.

7.2.1. Tourism

7.2.1.1. Length of the window of opportunity for vector-borne diseases

Vector Suitability Index for Aedes Albopictus (Asian Tiger Mosquito)

Climate change can influence the transmission of vector-borne diseases (VBDs) through altering the habitat suitability of insect vectors. This is mainly controlled by increases of ambient air temperature and changes in the hydrological cycle.

We explore if potential changes to meteorological conditions can affect the distribution of the Asian tiger mosquito (*Aedes albopictus*). The Asian tiger mosquito is native to the tropical and subtropical areas of Southeast Asia. In the past few decades, however, this species has spread to many countries through the international transport of goods and increased travel (Scholte and Schaffner, 2007). It is of great epidemiological importance since it can transmit viral pathogens and infectious agents that can cause chikungunya, dengue fever, yellow fever and various forms of encephalitis (Proestos *et al.,* 2015).

The multi-criteria decision support vector distribution model of Proestos *et al.* (2015) has been employed to estimate regional habitat suitability maps (not shown), based on previous work on the environmental/climatic factors affecting the life cycle of the Asian tiger mosquito (Waldock *et al.,* 2013; Proestos *et al.*, 2015). The mosquito habitat suitability model combines seven meteorological indices based on field observations, extensive literature review and expert knowledge.

For Fehmarn and its relatively northern latitudinal location, climate change is expected to affect the habitat suitability of *A. albopictus*. Precipitation and relative humidity are expected to increase under future conditions, while the temperature range in a future climate is expected to provide a more optimal environment for the establishment and spread of specific mosquito populations. This would change the habitat suitability from currently moderate levels to high suitability (see **Figure 7.2**).

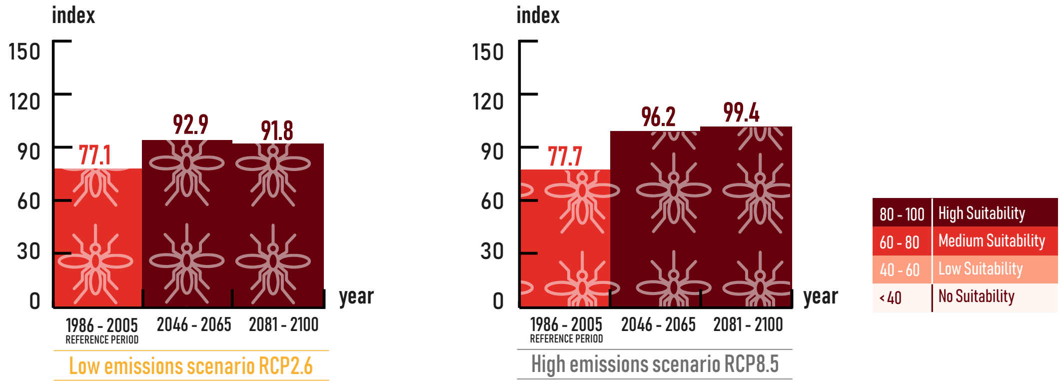


Figure 7.2. Habitat Suitability Index (HSI). 80-100: High Suitability; 60-80: Medium Suitability; 40-60: Low Suitability; <40 No Suitability.
Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed hazard indexes and indicators.

7.2.1.2. Humidity Index

For the assessment of heat-related impacts of climate change on human health, the humidity index (Humidex) (Masterton and Richardson, 1979) has been used. The Humidex value expresses the temperature perceived by people (the one that the human body would feel), given the actual air temperature and relative humidity. As a representative indicator for the assessment of inhabitants' and tourists' hazard on heat related climate change impacts, the number of days with Humidex values greater than 35 °C were selected. From the above classification, a day with Humidex above 35 °C describes conditions ranging from discomfort to imminent danger for humans.

For Fehmarn, N = 2 grid cells were retained from the model's domain. In Figure 7.3, the ensemble mean is presented for all periods and RPCs. It is found that for the present climate and the near future, the days with discomfort are very scarce (1-2 days per year), but a larger number of discomfort days could prevail under the RCP8.5 scenario at the end of the century (6 days) (see **Figure 7.3**).

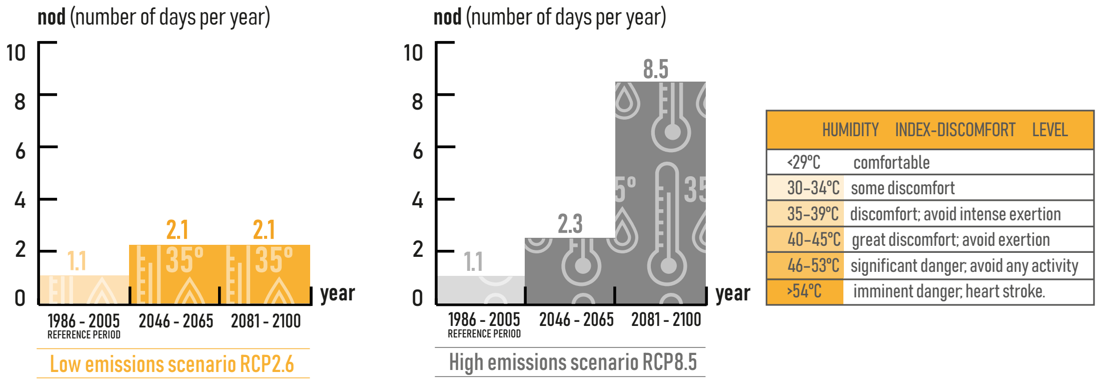


Figure 7.3. Number of days per year with Humidex > 35° C (Euro-CORDEX).

Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed hazard indexes and indicators.

7.2.2. Energy

A series of indicators related to renewable energy productivity is presented. The productivity and variability of these renewable energy sources will depend on climate. The possibility of reduced productivity due to climate change poses a risk to the energy generation, if it is based on these renewable energy sources. Also, a possible increase in the frequency and duration of solar and wind energy.

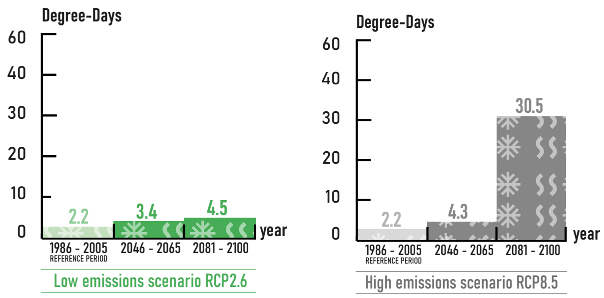


Figure 7.4. Cooling Degree Days. Ensemble mean of EURO-CORDEX simulations.

Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed hazard indexes and indicators.

7.2.2.1. Cooling Degree Days (CDD)

The Cooling Degree Days (CDD) index gives the number of degrees and number of days for which the outside air temperature at a specific location is higher than a specified base temperature. Therefore, it provides a measure for the severity of the heat during a specific period, taking into consideration outdoor temperature and average room temperature. The CDD index quantifies days during which active cooling of buildings becomes necessary.

For Fehmarn, N = 2 grid cells were retained from the model domains. In **Figure 7.4**, the ensemble mean is presented for all periods and RPCs. It is found that until the middle of the century in both scenarios, the increases in CDD index values are almost negligible, while towards the end of the century this number would be 15 times greater under RCP8.5, but not under RCP2.6. In consequence, even though there is currently no need for additional cooling on Fehmarn, the need will emerge in the future.

7.2.2.2. Available water: Standardized Precipitation Evaporation Index

The Standardized Precipitation Evaporation Index (SPEI) is used as an indication for water availability. Fehmarn island is the only case where the regional simulations suggest no significant changes in the occurrence of multiannual droughts. The precipitation increases projected for northern Europe are likely counterbalanced by the increases in temperature. Therefore, no significant SPEI changes are expected for this region and the SPEI values are expected to remain in the "normal" range (see **Figure 7.5**).

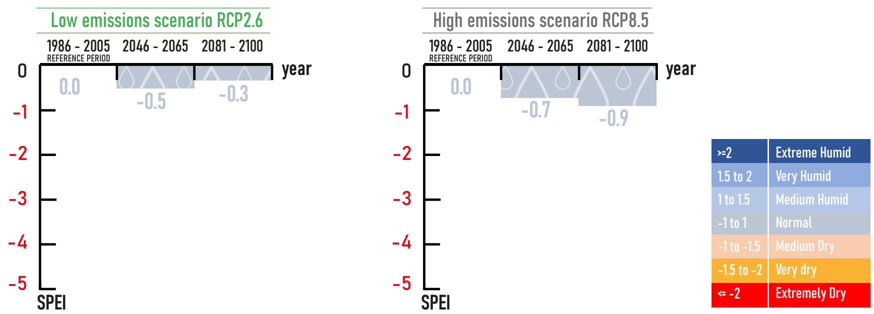


Figure 7.5. Ensemble mean values of the Standardized Precipitation Evaporation Index (SPEI).

Source: SOCLIMPACT Deliverable Report Report - D4.3. Atlases of newly developed hazard indexes and indicators.

7.2.3. Maritime Transport

7.2.3.1. Sea Level Rise (SLR)

Sea Level Rise (SLR) is one of the major threats linked to climate change. It could induce permanent flooding of coastal areas with a profound impact on society, economy, and environment. Moreover, an increase in the mean sea level would result in a larger impact of coastal storms with the consequent increase of risk. The results are presented in terms of expected mean SLR. For Fehmarn, the SLR predictions range from 20 cm (RCP2.6) to 57 cm (RCP8.5) at the end of the century (see **Figure 7.6**).

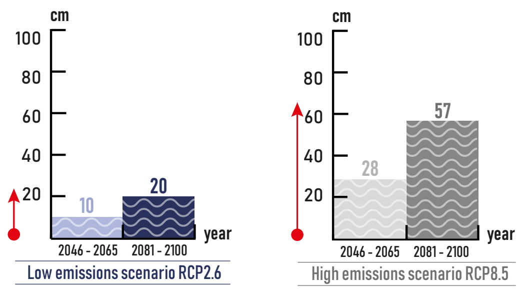


Figure 7.6. Mean sea level rise (in cm) with respect to the reference period (1986-2005). Own elaboration based on global and regional simulations.

Source: SOCLIMPACT Deliverable Report - D4.4b on storm surge levels.

7.2.3.2. Wind extremes

The wind extremity index NWIX98 is defined as the number of days per year that exceed the 98th percentile of mean daily wind speed. This number is predicted to increase from currently 7.3 days to 9.5 days at end of the century under the RCP8.5 scenario, an increase by 30.6%. In the low emissions scenario RCP2.6, the number of days is predicted to decrease from 7.3 to 6.1 days per year (see **Figure 7.7**).

7.3. Impact on the Blue Economy Sectors

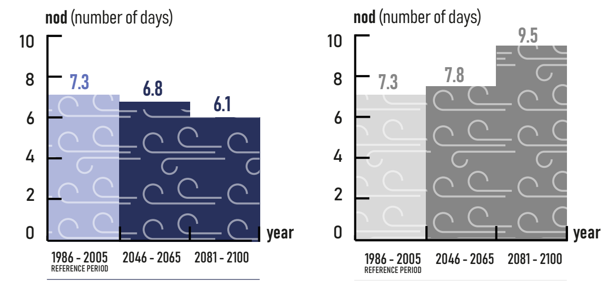


Figure 7.7. Wind Extremity Index (NWIX98). Ensemble mean of the EURO-CORDEX simulations.

Source: SOCLIMPACT Deliverable Report Report - D4.3. Atlases of newly developed hazard indexes and indicators.

7.3.1. Tourism (Non-Market Analysis)

In order to analyse the attitudes of tourists towards the impacts of climate change and the preferences for adaptation policies, several hypothetical situations were posed to them via questionnaires, whereby possible climate change impacts were outlined for the island (i.e., beach erosion, infectious diseases, forest fires, marine biodiversity loss, heat waves, etc.).

Firstly, tourists had to indicate whether they would keep their plans to come to the island or whether they would rather find an alternative destination if the impact were to occur. This knowledge can inform predictions on future tourist arrivals for each island. Secondly, tourists were asked to choose between various policy measures funded through an additional payment per day of stay – the tourists' choices being an expression of their preferences for attributes/policies. Using the Stata software, the ASC-Logit model was run to assess the results.

On Fehmarn, 196 tourists visiting the island were surveyed. The results are presented in **Figures 7.8** and **7.9.**

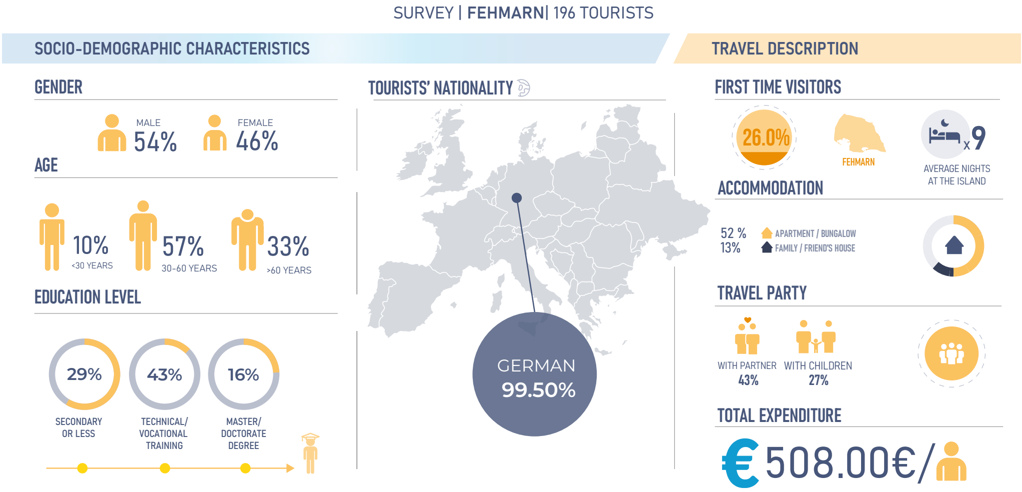


Figure 7.8. Socio-economic characteristics and travel description: tourists visiting Fehmarn.

Source: SOCLIMPACT Deliverable Report D5.5. Report on market and non-market costs of Climate Change and benefits of climate actions for Europe.

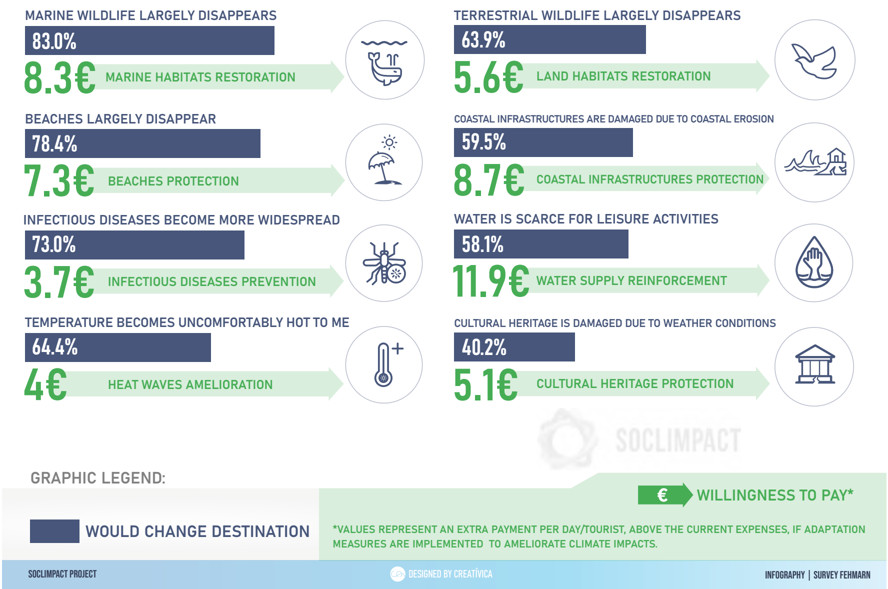


Figure 7.9. Tourists' response to climate change impacts and related policies: tourists visiting Fehmarn.

Source: SOCLIMPACT Deliverable Report D5.5. Market and non-market analysis. Report on market and non-market costs of Climate Change and benefits of climate actions for Europe.

In general, data confirmed that tourists are highly averse to the risk of marine wildlife disappearing to a large extent (83 % of tourists would change destination). Moreover, they would not be willing to visit the island if beaches largely disappeared (78.4 %) or if infectious diseases became more widespread (73 %). Consequently, policies related to water supply reinforcement (10.4 €/day), marine habitat restoration (9.3 €/day), and beaches protection (7 €/day) are on average the most valued adaptation measures among Fehmarn tourists.

Although climate change impacts are outside the control of tourism practitioners and policy-makers, they can nevertheless utilise this knowledge to improve the predictability of the effect that certain adaptation policies and risk management strategies could have on tourism flows, and develop their plans accordingly.

7.3.2. Maritime Transport

For maritime transport, the impact of SLR on each island's port operability costs was estimated. The costs have been calculated with reference to a 1 meter SLR, i.e., the investment needed to increase the infrastructures' height by 1 meter. There is not necessarily a strict correspondence between the SLR and the required elevation of port infrastructures, which also depends on the coastal hydrodynamic and the shape of dikes of each port. With the help of experts' recommendations, we assumed that a 1 meter increase in port height is required to cope with most predicted SLR under the RCP8.5 scenario. Extrapolation for other RCP scenarios was then conducted based on proportionality.

The starting point was the identification of the economic relevance of principal ports on each island. Secondly, the different port areas (exterior, ramps, oil, etc.), and their uses were analysed. Thirdly, the elevation costs were estimated per each area and port separately (considering an elevation of 1 meter). Thus, the costs for a 1 meter elevation are presented as the sum of all areas and ports analysed, proportionally including other ports on the island (if applicable). Estimates consider that all port areas of the entire zone should be elevated at the same time. In other words, the economic values can be interpreted as the depreciation (amortization) costs of the investment needed to increase all port infrastructures on an island for the 125-year-modelling time horizon. No discount rate was applied.

As expected, SLR is predicted to affect the maritime transport sector, and new investment will be needed to keep ports operational. Under the high emissions scenario, it is expected that these costs will range from 0.488 million (mid-century) to 0.994 million euros per year by the end of the century (see **Figure 7.10**).

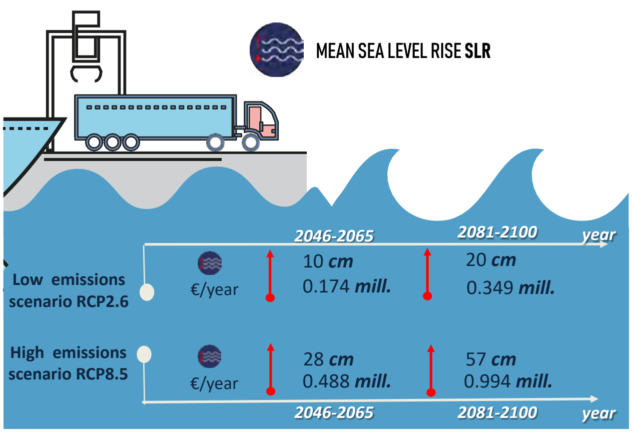


Figure 7.10. Increased costs for maintaining ports' operability in Fehmarn under different scenarios of SLR caused by climate change until 2100.

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

7.4. Towards Climate Resiliency

For Fehmarn, climate politics are applied on different, partially independent, political levels. Mitigation concepts do exist on several levels of governance (national, federal state of Schleswig-Holstein, Region of Ostholstein, City of Fehmarn). There is an Adaptation Strategy to Climate Change of the federal state of Schleswig-Holstein and on a national level (2017). Although it provides an important framework (for example, on coastal protection and dyke building), it does not cover island specific measures that address locally specific issues/problems.

The picture looks different when considering adaptation policies. While there is a strategy for climate adaptation on national and federal state levels, such strategies are still missing on a regional or island-wide level. An exception are coastal protection and dyke building plans that always existed for coastal regions in Germany. On the island level, Fehmarn stakeholders are open to develop strategic answers to climate change.

The commitment for climate adaptation in the region is limited, due to the lack of political commitment, budget availability and personal capacities for climate adaptation. Most municipalities have not yet discussed adaptation measures apart from the traditional coastal protection and dyke building plans. However, signs of change are slowly starting to emerge. The very hot summers of 2018 and 2019 have shown the need for action, and the national government is beginning to finance scientific research and projects that develop good practice implementation principles.

Nevertheless, personal capacities for climate adaptation in the administrations of regions/municipalities are still not existent (if they are, only on a project-funded basis), so that budgets are not coherent and are distributed over several already existing sectors, such as firefighting, building, health, port administration, and beach management.

Island-specific data is lacking due to the small size of the island. The resolution of climate models is insufficient, also socio-economic is in most cases only available on district or federal state level. Secondly, the need to adapt to climate change is not widely seen yet as many still believe that the mild central european climate would not change drastically and if so it is regarded as being more of an advantage for tourism than a threat, as the weather gets warmer and the season longer. Nevertheless, consciousness has risen on Fehmarn due to the SOCLIMPACT Project but also the Fridays for Future movement and some recent extreme weather events, of which the heat and the drought in the summer 2018 had the biggest impact, leading to a declaration of climate emergency by the municipal council.

7.4.1. Policy Recommendations

A stakeholders consultation process was carried out in the island, aiming to propose, analyse and rank alternative adaptation measures for the island. The profile of the individuals participating in these focal groups involved policy and decision-makers, practitioners, non-governmental and civil society organisations, science experts, private sector, business operators and sector regulators at island level.

The main aim of these meetings was:

1. Identify and present the characterized packages of adaptation and risk management options for the island.
2. Develop detailed integrated adaptation pathways in three timeframes: Short term (up to 2030), Mid-century (up to 2050) and End-century (up to 2100).
3. Evaluate and rank adaptation options for the tourism sector in the island.

To this aim, stakeholders utilized five evaluation criteria to rank the proposed measures:

- Cost efficiency: Ability to efficiently address current or future climate hazards/risks in the most economical way.
- Environmental protection: Ability to protect the environment, now and in the future.
- Mitigation win-wins and trade-offs: Current ability to meet (win-win) or not (trade-off) the island / archipelagos mitigation objectives.
- Technical applicability: Current ability to technically implement the measure in the island.
- Social acceptability: Current social acceptability of the measure in the island.

Four scenarios of intervention were analysed, called Adaptation Policy Trajectories, which are different visions of future policy adaptation choices:

- APT A Minimum Intervention - Low investment, low commitment to policy change.
- APT B Economic Capacity Expansion - High investment, low commitment to policy change.
- APT C Efficiency Enhancement - Medium investment, medium commitment to policy change.
- APT D System Restructuring - High investment, high commitment to policy change.

It was assumed that adapting to climate change may range from minimal to high cost, and from requiring a small or incremental change to a significant transformation from the *status quo*. However, not all APT scenarios were considered in all islands, especially when their stakeholders had a clear vision on the types of measures with greatest viability. Therefore, the final set of proposed adaptation measures are framed in the islands' socio-economic and political context, have a sectoral perspective, and respond to the islands' future scenarios of climate change. At the same time, the involvement of regional stakeholders in policy design allows them to engage in the effective implementation of climate actions on their island.

In Appendices from K to N, a brief explanation of each adaptation option can be found, classified by type or class: Vulnerability Reduction, Disaster Risk Reduction, Social-Ecological Resilience, and Local Knowledge. The latest group refers to very specific measures proposed by stakeholders in each island to ratify the needs.

7.4.1.1. Tourism

Measures that address the issue of climate change adaptation through a Vulnerability Reduction showed that for most of the choices the stakeholders had clear preferences on which option to choose over time. "Activity and product diversification" were the most selected AO across all scenario worlds, being chosen 75% of the time when the question was asked. It was the preferred measure to be implemented in all 4 APTs across all three-time frames. During the webinar, it became clear that "activity and product diversification" was considered a very broad term, potentially explaining why it was so popular. By being unspecific, it could encompass a whole range of activities with different capacity of durability and climate adaptation capacity, so that stakeholders making this choice could choose it as a flexible option that does not require to have specific activities in mind. The opposing choice, "information campaigns", did never enter the adaptation trajectories and was not considered a viable option to combat and prepare for climate change. This finding is interesting as communities, including Fehmarn, seem to often support and promote information campaigns to educate the public. There seems to be a discrepancy between activities and perceived usefulness. Potentially stakeholders had no clear idea of the implications of information campaigns.

It could be observed that choosing different scenario worlds could lead to differential outcomes. In the case of the choice between "economic policy measures" and "financial incentives to retreat from high-risk areas", it seemed to matter whether a stakeholder imagined being on trajectory B or D, the two APTs in which this choice was available. In APT B, policy measures were chosen across all time steps, whereas in APT D, the two options were on par in the first-time step (up to 2030), after which the retreat incentives were chosen until the end of the century.

Contrary to this, for the choice between "water-saving and grey water recycling" and "local sustainable fisheries," it did not seem to make a difference whether the choice was made in APT C or D. In both worlds, "local fisheries" were preferred at the beginning and middle of the century, whereas the "water measures" were chosen more at the middle to end of the century. This choice, in combination with the finding that "desalination measures" were also preferred towards the end of the century, might indicate that measures that appear to deal with heat and water scarcity seem to gain importance towards the end of the century. Possibly, this is informed by the climate projections that predict summers to become hotter, as well as past experiences, e.g., the summer of 2018, during which Fehmarn municipality declared water shortages and asked citizens and tourists to cut down on their water consumption.

"Local circular economy" was a popular choice among stakeholders, being picked 73% of the time and entering the adaptation pathway across all three-time frames in APT C, the only scenario world in which the option was present. When asking the stakeholders how they imagined such a circular system to work, they focused on rather small-scale activities. One stakeholder suggested utilising seagrass that has been washed onto the shore as biomaterial to build housing insulations, fertilise agricultural land, and create products such as pillows. Another stakeholder mentioned that existing projects, like a local dish and cup deposit scheme, could be expanded upon. Although the options were popular, the stakeholders did not have concrete ideas on how a truly circular economy would look like on Fehmarn.

For measures concerning Disaster Risk Reduction, the trend in which AOs concerning water scarcity alleviation were primarily chosen towards the end of the century continued. "Drought and water management plans" were never chosen in the first-time frame but always at the end of the century. They were also chosen three out of four times in the middle of the century. This was explained by one stakeholder during the webinar. The climate predictions for the end of the century look more dramatic than the current climate situation. Implemented measures need to be explained by politics and decision-makers. If there is no evident necessity at the moment or soon, then the financial investment is not justified, as the cost to benefit calculations are not in the favour of the adaptation measure.

"Coastal protection structures" were chosen in the beginning and middle of the century. In APT A, it was chosen throughout all periods. The rationale behind these choices could be that stakeholders might consider it important to build up structures early to avoid consequences from sea level rise towards the end of the century. The webinar revealed that trust in the local protection structure surveillance is high. Indeed, the general opinion was that if high and extensive coastal protection structures are built now, then this will be one issue less to worry about towards the end of the century. It was also mentioned that the pattern of this choice could indicate a certain optimism regarding protection structures being needed in the near future, but towards the end of the century, one could be hopeful that the rising sea level trends are stopped, lessening the need for building more protective structures.

The choice for "medical systems improvement" was made across all time frames in APT A, the only trajectory where it could be chosen. Surprisingly, it was on par with "fire management plans" in the beginning and end of the century, but not in the middle of the century. As those two choices entered the trajectory to almost equal parts in all time frames, there does not seem to be a clear preference on which AO is more important. This might indicate different perspectives, where some stakeholders might consider the medical service to be underdeveloped, whereas others consider the fire department, which also frequently aids in disaster management in Germany, to be not sufficiently developed. This might depend on stakeholder's personal experiences with past droughts and other disasters or illnesses.

"Pre-disaster management plans" vs "Post-disaster financial funds" showed that stakeholders tended to pick the financial aid in the beginning and end of the century, whereas the pre-disaster preparation seemed more relevant at the end of the century, potentially indicating that stakeholders might consider disaster preparation from an organised or municipal entity more important, as climate risk and severity are predicted to increase at the end of the century. Financial support might be considered adequate towards the beginning and middle of the century to overcome the impacts of climate change or severe weather events.

Selection choices for adaptation options that are aimed at fostering Social-Ecological Resilience also yielded interesting trends for Fehmarn. "Adaptation of the groundwater management system" was the dominant choice in this category and entered the adaptation trajectories in all four APT scenarios and across all time frames, apart from the end of the century in APT D, where "monitoring, modelling and forecasting systems" were chosen. Such a clear choice preference might have to do with the island's climate predicted to become hotter and drier in the summer. So far, the island's freshwater is supplied via a connection to the mainland. However, from the workshop, we identified the desire that stakeholders would like the island to become more independent and less reliant on the mainland supply, potentially leading to the desire to improve their groundwater management. Consultations during the second webinar yielded that is not so much the supply of freshwater that is considered a potential issue in the future, but the quality of the groundwater on the island. Dry summers, as well as more industrialised activity and over-usage of soils, are considered a threat to the groundwater on Fehmarn.

"Monitoring, modelling and forecasting systems" entered the trajectories in APTs B, C, and D at the end of the century, although across all choices, they were only picked 37% of the time. This shows that stakeholders might be interested in knowing specific occurrences of events when climate hazards are more common rather than establishing these systems now and being in a continuously alerted state. During the webinar, we could find that the climate hazards of the near future are still considered to be manageable, whereas towards the end of the century the predictions seemed more dramatic, warranting forecasting systems.

"Dune restoration and rehabilitation measures" got chosen across all time frames when the option was available. Dunes are playing an important role on the island, both as natural coastal protection measures, but also from a touristic perspective. It was, therefore, a clear choice to pick, as the other option was "river rehabilitation and restoration", an option that was not important as there are no large rivers on the island and only a few small canals to drain fields.

"Restoring and managing natural habitats adaptively" was chosen in the beginning and middle of the century, whereas "establishment of ocean pools" came into play at the end of the century. This is interesting, as Fehmarn is an island that has several larger beach lakes functioning effectively as ocean pools. With rising sea levels, stakeholders seem to consider it important to establish more of these to have more natural protection from stormwater surges and rising sea levels (see **Table 7.1**).

Table 7.1. Proposed adaptation options for tourism in Fehmarn.

<table>
<tr><td rowspan="6">APT A – Pathway
—
Minimum Intervention
low investment, low commitment to policy change
—
This policy trajectory assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts</td><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td colspan="3">Activity and product diversification</td></tr>
<tr><td colspan="2">Coastal protection structures</td><td>Drought and water conservation plans</td></tr>
<tr><td>Fire management plans</td><td colspan="2">Health care delivery systems</td></tr>
<tr><td colspan="2">Post-disaster recovery funds</td><td>Pre-disaster early recovery planning</td></tr>
<tr><td colspan="3">Adaptation of groundwater management</td></tr>
<tr><td rowspan="7">APT B – Pathway
—
Economic Capacity Expansion
high investment, low commitment to policy change
—
This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy</td><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td colspan="3">Economic Policy Instruments (EPIs)</td></tr>
<tr><td colspan="3">Activity and product diversification</td></tr>
<tr><td colspan="2">Beach nourishment</td><td>Desalination</td></tr>
<tr><td>Coastal protection structures</td><td colspan="2">Drought and water conservation plans</td></tr>
<tr><td colspan="2">Adaptation of groundwater management</td><td>Monitoring, modelling and forecasting systems</td></tr>
<tr><td colspan="3">Dune restoration and rehabilitation</td></tr>
<tr><td rowspan="9">APT C – Pathway
—
Efficiency Enhancement
medium investment, medium commitment to policy change
—
This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system</td><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td colspan="3">Activity and product diversification</td></tr>
<tr><td colspan="3">Local circular economy</td></tr>
<tr><td>Local sustainable fishing</td><td colspan="2">Water restrictions, consumption cuts and grey-water recycling</td></tr>
<tr><td>Coastal protection structures</td><td colspan="2">Drought and water conservation plans</td></tr>
<tr><td colspan="2">Mainstreaming Disaster Risk Management</td><td>Using water to cope with heat waves</td></tr>
<tr><td>Monitoring, modelling and forecasting systems</td><td colspan="2">Adaptation of groundwater management</td></tr>
<tr><td colspan="3">Dune restoration and rehabilitation</td></tr>
<tr><td colspan="2">Adaptive management of natural habitats</td><td>Ocean pools</td></tr>
<tr><td rowspan="7">APT D – Pathway
—
System Restructuring
high investment, high commitment to policy change
—
This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems</td><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td>Economic Policy Instruments (EPIs)</td><td colspan="2">Financial incentives to retreat from high-risk areas</td></tr>
<tr><td colspan="3">Activity and product diversification</td></tr>
<tr><td>Local sustainable fishing</td><td colspan="2">Water restrictions, consumption cuts and grey-water recycling</td></tr>
<tr><td colspan="2">Coastal protection structures</td><td>Drought and water conservation plans</td></tr>
<tr><td>Post-disaster recovery funds</td><td colspan="2">Pre-disaster early recovery planning</td></tr>
<tr><td colspan="2">Adaptation of groundwater management</td><td>Monitoring, modelling and forecasting systems</td></tr>
</table>

Vulnerability Reduction *Disaster Risk Reduction* *Socio-Ecological Resilience* *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3 Workshop Reports.

Chapter

8

Madeira (Portugal)

SOCLIMPACT

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 776661

CONTENTS

Madeira at a Glance

Madeira archipelago, discovered in 1419, is a Portuguese autonomous region located in the Atlantic Ocean (978 km southeast Lisbon and 700 km west Africa). Madeira, with 741 km^2 and 249 052 residents, and Porto Santo, with 42 km^2 and 5 2020 residents, are the inhabitant islands. Funchal, in Madeira, is the capital city.

Until the 17th century, sugarcane was the economy driver of Madeira, followed by "Madeira wine" production. Currently, tourism is the main economic activity, being the fertile vegetation and the landscape the greatest attractions. The nature reserve covers two thirds of the territory, being Laurissilva forest the only UNESCO Natural World Heritage Site in Portugal.

In Porto Santo, seasonal tourism during summer is the main economic activity, being the 9 km golden sand beach, the turquoise sea, the geologic heritage and the peaceful environment the main attractions.

Desertas and Selvagens islands are biodiversity conservation territories, with special protection status.

The Blue Economy Sectors

- **Aquaculture**

  In Madeira archipelago, the economic significance of aquiculture is small, being the production in open sea restricted to the south coast of Madeira island, where two companies produce seabream. After an initial experience, the activity restarted in 2005.

  The production oscillated between 169 tonnes in 2011, and 570 tonnes in 2013. The regional market consumes an average of 150 tonnes of local aquiculture production per year.

  Since 2001, "Centro de Maricultura da Calheta", a research centre, produces juvenile fish for aquiculture, provides training and technical support to private fish farming companies, and develops research, namely on the production of local species.

- **Maritime Transport**

  Madeira archipelago is highly dependent on freight maritime transport. Cruise activity is important to the tourism sector in Madeira. The maritime transport is strategic to connect the inhabited islands.

  Madeira has two ports in the south coast. The Caniçal port is for freight traffic and Funchal port for touristic purposes, being also used by the ferry that connects the islands. Small boat marinas and ports exist around Madeira for recreational and fishing activities. The north coast sea makes difficult the operation of larger port facilities. Porto Santo has a port facility for freight and passenger transport, being strategic for tourism.

- **Energy**

  The Madeira archipelago is highly dependent on fossil fuels (79% primary energy, 2018). The electricity generation from renewables is limited by the small and isolated electricity systems, which demands significative investments in energy storage and smart grids, to guaranty the quality and security of supply.

  The dependence on maritime and air transports, and land mobility limited on road transports, make challenging the energy mix diversification for transports (50% final energy, 2018).

  The islands isolation, fragmentation and small size entails high investments in redundancy infrastructures, namely for electricity generation and energy storage, and increases the energy system vulnerability to climate change.

- **Tourism**

  Tourism is the main economic activity in Madeira archipelago and does not have mass tourism characteristics. In Madeira island the activity is not seasonal. The mild climate, nature, landscape and special events are main attractions. Sea and mountains are geographically close providing a wide range of experiences. Hiking in Laurissilva forest and alongside water channels, and sea activities are particularly appreciated. Since 2014, more than one million tourists arrive each year to Madeira. Porto Santo Island has seasonal tourism, being its sandy beach the main attraction. Peaceful environment, geologic heritage, special events and sports are being explored to decrease seasonality.

8.1. Current Climate and Risks

Madeira Island has a very mild climate. Its geographical location and orography defines avariety of microclimates with dense vegetation (Laurissilva forest), particularly on the north side. The Funchal average temperature is 23°C in summer and 18°C in winter. The annual average temperature is 19°C

CURRENT CLIMATE-RELATED RISKS

- Coastal flood High

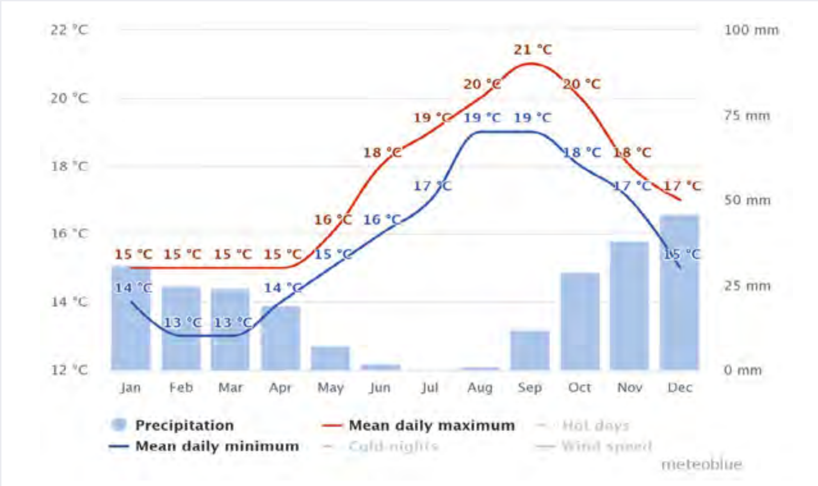
SIGNIFICANT CLIMATE EVENTS

- Flash Floods (2010, 2013)
- Destructive waves (2013)
- Wind storms (2018)
- Fire (2012, 2016)
- Sea storm (2018)

in the south coast, 16 °C in the north, and 8 °C in the highest peaks (1800 meters). The sea temperature is very mild, with an average temperature of 23 °C in summer and 18 °C in winter. The rains are more frequent between October and May. Given the orography and the prevailing north-easterly winds, the rains are more regular and abundant in north-facing slopes. In summer, rainfall is less frequent and abundant, especially in south side and coastalareas. Porto Santo island has an average temperature of 22 °C in summer and 17 °C in winter. These temperatures are similar to Madeira's. Rainfall is less abundant in this island, defining a drier landscape (see **Figure 8.1**).

CLIMATE CHARACTERISTICS (37.74°N 25.67°W, 10m asl)

Average temperature and precipitation



Wind speed

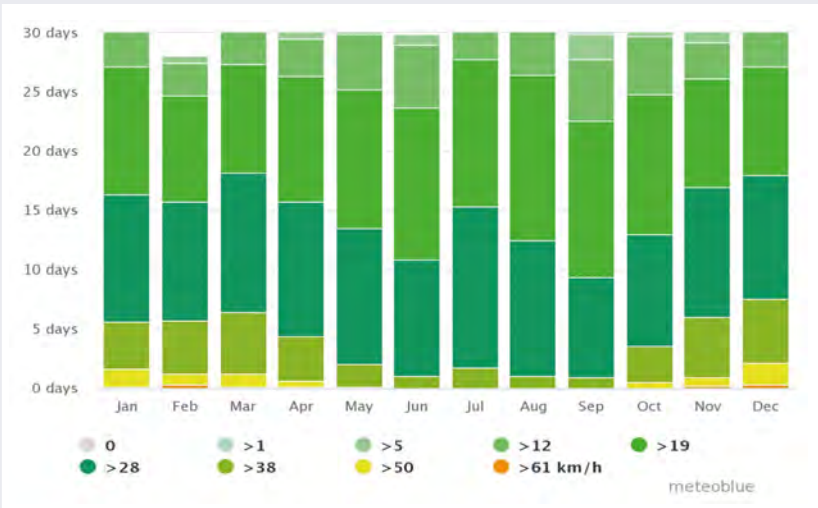
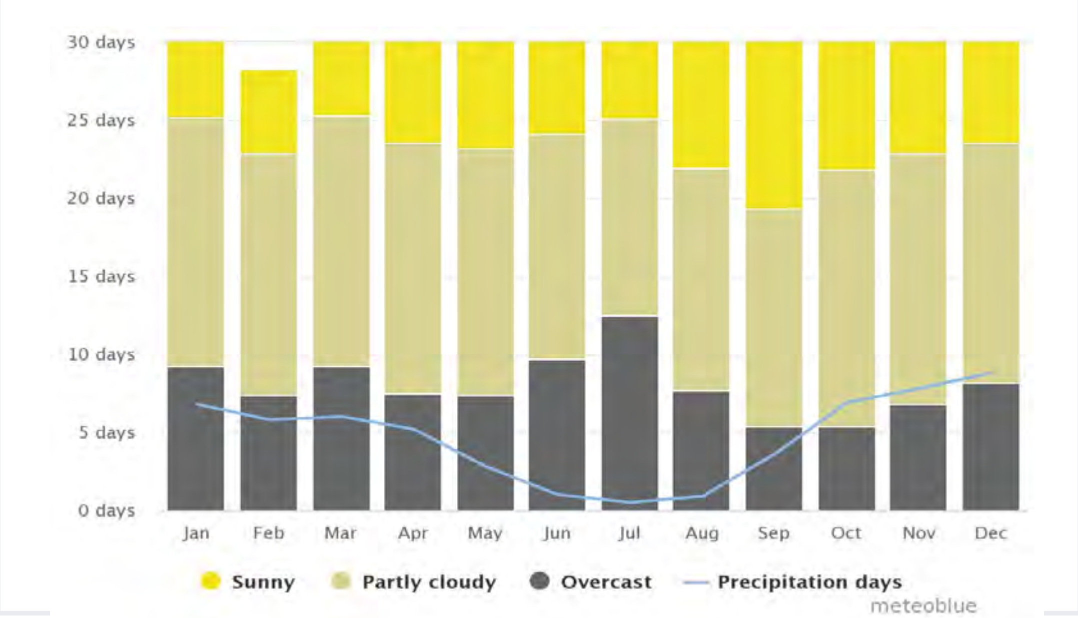


Figure 8.1. Climate factsheet.

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System). ***(Continued on the next page)***

Cloudy, sunny and precipitation



Wind rose

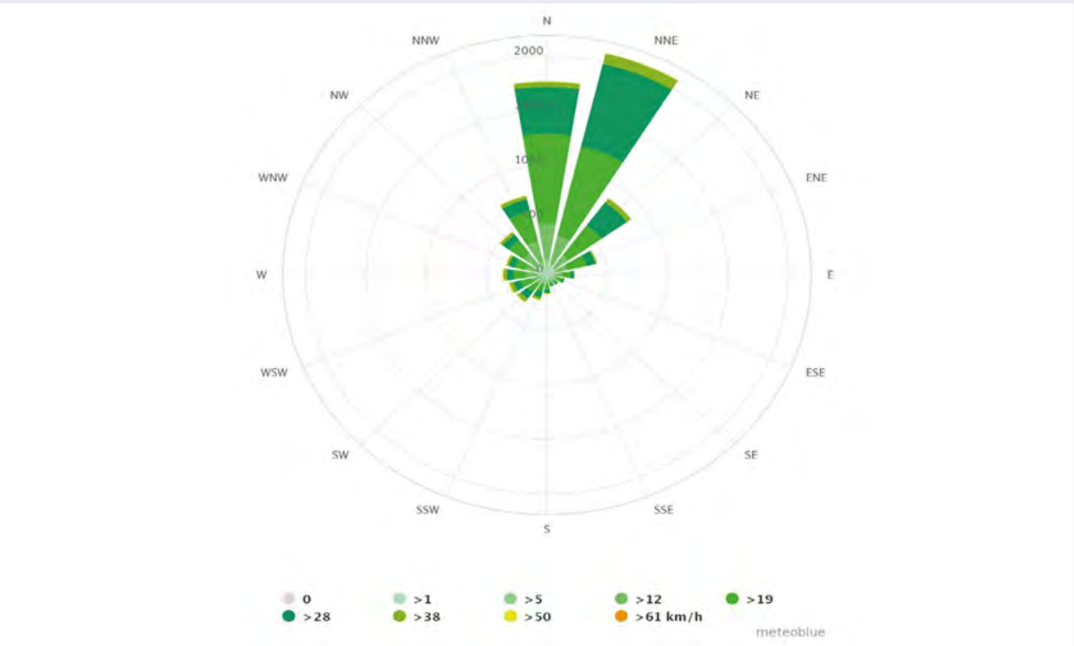


Figure 8.1 (Cont.). Climate factsheet.

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System).

8.2. Macroeconomic Projections

It is expected that Madeira's GDP continues to grow throughout the 2015-2100 period. The main drivers of growth are private consumption and investments over the whole projection period (see **Table 8.1**).

Respective GDP-shares of private consumption and investments remain relatively stable over the projections period (see **Figure 8.2**). Investments grow at a high pace in 2020. However, these growth rates decline steadily afterwards. The trade deficit is assumed to be reduced in the long run.

Table 8.1. Madeira GDP and GDP components yearly growth rates in 2020-2100.

	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
GDP	2.5%	1.3%	1.3%	1.2%	1.1%	1.0%	0.9%	1.2%	1.0%	1.4%
Private consumption	3.4%	1.8%	1.7%	1.5%	1.4%	1.3%	1.2%	1.1%	0.8%	1.0%
Public consumption	-0.3%	-0.2%	-0.2%	-0.3%	-0.4%	-0.6%	-0.7%	1.1%	0.8%	1.0%
Investments	3.1%	1.7%	1.5%	1.4%	1.3%	1.3%	1.2%	1.0%	1.0%	1.0%
Trade	3.1%	1.7%	1.5%	1.4%	1.3%	1.3%	1.2%	0.9%	0.6%	-0.5%

Deliverable 6.2. Macroeconomic outlook for the islands.

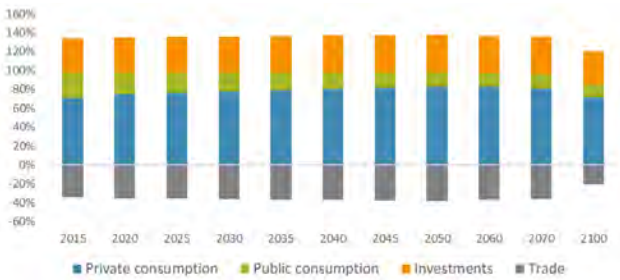


Figure 8.2. Macroeconomic components as a% share of GDP for Madeira in 2015-2100.

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

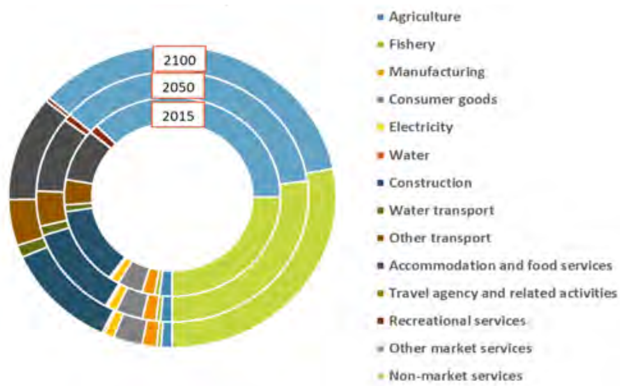


Figure 8.3. Sectoral value added as a% share to total GVA for Madeira in 2015, 2050 and 2100.

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

8.2.1. The Sectoral Projections

It is estimated that Madeira's economy remains a service-led economy throughout the 2015-2100 period, with significant contributions to total gross value added from construction, non-market services, accommodation and food services, and other market services (see **Figure 8.3**).

Agriculture, fishery, manufacturing and consumer goods sectors are projected to contribute, in total, less than 6% to the economy-wide gross value added, in 2100.

Total tourism activities are projected to experience a long run increase of their respective gross value-added shares. Starting from more than 11% in 2015, this share is projected to increase steadily to more than 14% until 2100[1] (see **Table 8.2**).

1 The share of tourism in GDP is calculated via the tourism satellite account (TSA) matrices of 2015, assuming that the same shares that indicate the contribution of tourism to the productions of tourism-related sectors (such as the accommodation and food services, transport services, travel agency and related activities, cultural and recreational activities) remain throughout the 2015-2100 period. Please, see Appendix B of the *D.6.2: Macroeconomic outlook for the islands* for the complete database of the estimated TSAs.

Table 8.2. Sectoral contribution as a% share of total gross value added for Madeira in 2015-2100.

GVA% shares	2015	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
Agriculture	1.9%	1.7%	1.6%	1.6%	1.5%	1.5%	1.4%	1.4%	1.3%	1.3%	1.1%
Fishery	0.7%	0.7%	0.6%	0.6%	0.6%	0.6%	0.5%	0.5%	0.5%	0.5%	0.4%
Manufacturing	1.9%	1.8%	1.7%	1.7%	1.7%	1.7%	1.6%	1.6%	1.6%	1.5%	1.4%
Consumer goods	3.8%	3.6%	3.5%	3.4%	3.4%	3.3%	3.3%	3.2%	3.2%	3.1%	2.9%
Electricity	1.3%	1.2%	1.2%	1.2%	1.1%	1.1%	1.1%	1.1%	1.1%	1.1%	1.0%
Water	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.2%
Construction	12.7%	11.9%	11.8%	11.7%	11.7%	11.7%	11.7%	11.8%	11.8%	11.8%	11.4%
Water transport	1.1%	1.1%	1.1%	1.2%	1.2%	1.2%	1.2%	1.2%	1.2%	1.3%	1.3%
Other transport	4.1%	4.2%	4.3%	4.4%	4.4%	4.5%	4.5%	4.5%	4.6%	4.7%	4.9%
Accommodation and food services	8.5%	8.4%	8.8%	9.1%	9.3%	9.5%	9.6%	9.8%	10.1%	10.3%	11.3%
Travel agency and related activities	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Recreational services	1.3%	1.5%	1.4%	1.2%	1.1%	1.0%	1.0%	0.9%	0.8%	0.7%	0.4%
Other market services	37.4%	37.5%	37.3%	37.1%	37.0%	36.8%	36.7%	36.6%	36.4%	36.2%	35.6%
Non-market services	25.0%	26.0%	26.3%	26.5%	26.7%	26.8%	26.9%	27.0%	27.2%	27.4%	28.0%

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

8.2.2. Employment

The service-led economic growth brings positive effects to the labour market with unemployment rates being continuously reduced throughout the projection period. The contribution of each sector to total employment depends on the labor intensity of the sector. The biggest employing sectors are the non-market and other market services as well as accommodation and food services. Construction services do also still provide significant employment contributions in 2100.

Tourism is the largest employer of the Blue Growth sectors under analysis, particularly due to the high labor intensity of accommodation and food services. Electricity, water transport and fisheries feature rather stable employment shares throughout the projection period. However, none of these sectors contributes individually more than 1% to total employment (see **Table 8.3** and **Figure 8.4**).

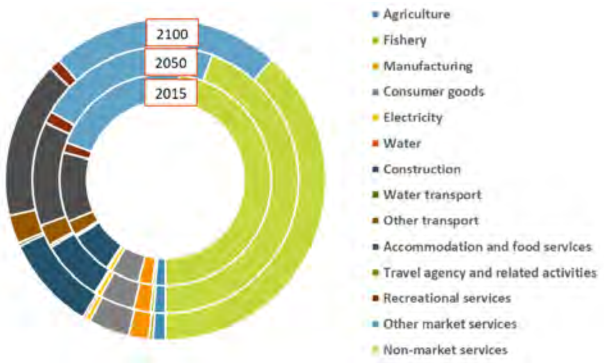


Figure 8.4. Sectoral employment as a% share of total for Madeira in 2015, 2050, 2100.

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

Table 8.3. Unemployment rate for Madeira in 2015-2100.

	2015	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
Unemployment rate	14.7%	11.7%	10.9%	10.3%	9.7%	9.0%	8.2%	7.4%	7.5%	7.5%	7.2%

Source: SOCLIMPACT project Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

8.3. Climate Change Outlook

Climate hazards indicators represent the entry point to understand the climate change exposure of the blue economy sectors. The indicators have been computed for two scenarios, RCP2.6 (ambitious mitigation scenario) and RCP8.5 (business as usual), and for different horizon times namely a reference period (1965-2005), mid-century (2046-2065) and end of century (2081-2100). Main source of climate projections (future climate) for Madeira is MENA-CORDEX ensemble even if other model sources were applied when required, depending of available scales. Results are presented in form of maps, tables or graphs and only when the information shows an interesting outcome.

As to its reliability, it is important to note that Atlantic islands (Azores, Madeira, Canaries and West Indies) lie in very critical areas where global models might be inaccurate in predicting the large scale patterns (regional models are not available), and resolution is so coarse that in fact many islands do not even exist in model orography. This acknowledged, this is the only information we can provide, and at least future tendencies can be inferred.

The new CMIP6 simulations might shed more light on this issues, but we can only suggest that results should be updated as they become available.

The same partly holds for the wave simulations: local resolution has been significantly increased in the dedicated new simulations of this project, performed by the partner ENEA (up to 0.05°), but the forcing wind field is still derived from the coarse global models.

Stakeholders should be made aware that uncertainty is an inherent characteristic of climate data, and that any future planning must cope with it. Climatologists can only highlight potential threats and constraints, they cannot predict the future and pave the way to solutions. Conveying this piece of information is one of the most critical points of climate change related information.

8.3.1. Tourism

8.3.1.1. Beach flooding and related losses

One of the consequences of an increase in the mean sea level will be the flooding of coastal areas. This includes sand beaches, which are the main asset for tourism activities in most of the European islands. Therefore, estimating the potential risk of beach loss due to climate change is of paramount importance for the economy of those islands.

The 95th percentile of the flood level averaged was selected as an indicator of interest. The values are presented as anomalies with respect to the present mean sea level at beach location (i.e., including the median contribution of runup).

In all cases, an increase is expected being larger at the end of the century under scenario RCP8.5. The larger values are found for the Atlantic islands, where slightly larger sea level rise is combined with the effect of much larger wind waves. The values in that scenario is 163 cm in Madeira. Under RCP2.6 scenario, the values are less than half, suggesting that a mitigation scenario could largely minimize the negative impact of climate change on beach flooding (see **Figure 8.5**).

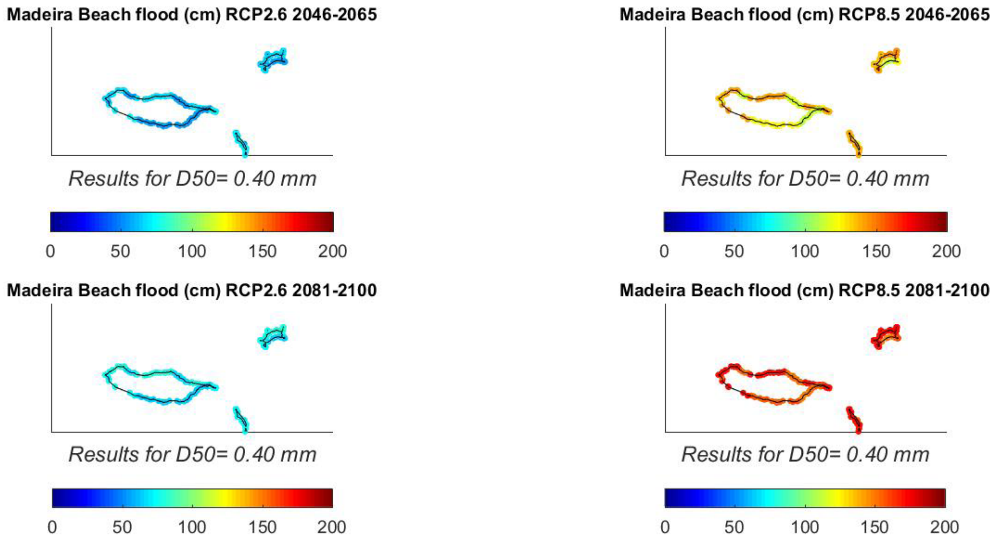


Figure 8.5. Projected extreme flood level (in the vertical, in cml) at beach locations with respect to the present (1986-2005) mean sea level values averaged for the islands under scenario RCP2.6 (left) and RCP8.5 (right). Own elaboration based on global and regional simulations.

Source: SOCLIMPACT Deliverable Report - D4.4d. Report on the evolution of beaches.

Under mean conditions, we find that, at end of century, the total beach surface loss range from ~57 % under scenario RCP2.6 to ~95 % under scenario RCP8.5 (see **Figure 8.6**).

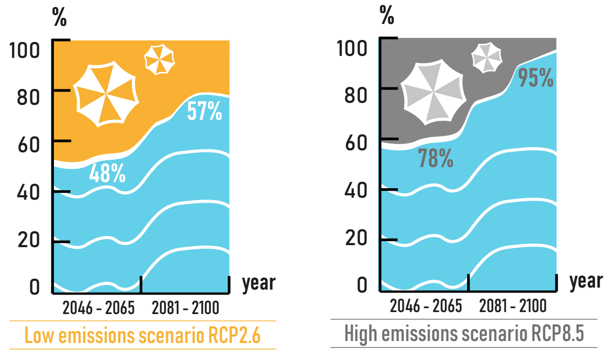
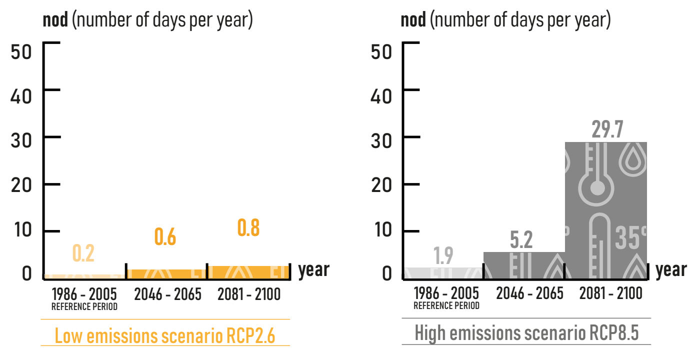


Figure 8.6. Beach reduction % (scaling approximation).
Source: SOCLIMPACT project deliverable D4.4d - Report on the evolution of beaches.

8.3.1.2. Humidex

For the assessment of heat related impacts of climate change on human health, the humidity index (Humidex) (Masterton and Richardson, 1979) has been used. Humidex value is an equivalent temperature, which express the temperature perceived by people (the one that the human body would feel), given the actual air temperature and relative humidity. As a more representative indicator for the assessment of inhabitants' and tourists' hazard on heat related climate change impacts, the Number of Days with Humidex greater than 35 °C was selected. From the above classification, a day with Humidex above 35 °C describes conditions from discomfort to imminent danger for humans.

For Madeira, two separate analysis were conducted, as RCP2.6 was available for only one model, while for RCP8.5 we used four GCM/RCM pairs. We find that for RCP2.6, the days with discomfort are negligible, though, the analysis of the RCP8.5 future projections shows that from less than 1 day in the present climate, the number increases to 30 days per year at the end of the century (see **Figure 8.7**).



HUMIDITY	INDEX-DISCOMFORT LEVEL
<29°C	comfortable
30-34°C	some discomfort
35-39°C	discomfort; avoid intense exertion
40-45°C	great discomfort; avoid exertion
46-53°C	significant danger; avoid any activity
>54°C	imminent danger; heart stroke.

Figure 8.7. Number of days per year with Humidex > 35° C (Euro-CORDEX).
Source: SOCLIMPACT project deliverable D4.3. Atlases of newly developed indexes and indicator.

8.3.2. Aquaculture

The predicted impacts of climate change on the oceans and seas of the planet are expected to have direct repercussions on marine based aquaculture systems. The basic effects are the following (Soto and Brugere, 2008):

- Change in biophysical characteristics of coastal areas.
- Increased invasions from alien species.
- Increased spread of diseases.
- Changes in the physiology of the cultivated species by changing temperature, salinity, oxygen availability and other important physical water parameters.
- Changes in the differences between sea and air temperature, which will alter the seasonality, frequency and severity of storms, cyclones and other extreme events, affect the stability of the coastal resources and potentially increase the damages in infrastructure.
- Sea level rise, acidification, changes in precipitation and other effects will also add to the changes in coastal ecosystems and environment, thus affecting production and infrastructure (= investments).

8.3.2.1. Fish Thermal Stress

Temperature changes in seawater trigger physical impacts; increased harmful algal blooms, decreased oxygen level, increase in diseases and parasites, changes in ranges of suitable species, increased growth rate, increased food conversion ratio and more extended growing season. Furthermore, all these impacts lead to socio-economic implications among them, changes in production levels and an increase in fouling and pests. The objective of the current analysis is to identify and quantify the variations (future climate scenarios with respect to present climate) in the number and in the duration of events characterized by a Sea Surface Temperature (SST) exceeding a given threshold. The SST thresholds have been identified according to the farming and feeding necessities of several marine species, particularly relevant for the aquaculture sector in the Mediterranean Sea (MS). For Madeira, the increase in sea surface temperature is expected to be critical for mussels and clams, with 200 days per year exceeding the threshold. For the case of seabass, the risk would increase 50 times (see **Figure 8.8**).

	Longest event (days) >20 degrees Mussels & clams	Longest event (days) >24 degrees Sea bream/Tuna	Longest event (days) >25 degrees Sea bass
Historic (1986-2005)	148 days	8 days	0 days
RCP 8.5 - mid century	195 days	30 days	18 days
RCP 8.5 - end century (2081-2100)	201 days	90 days	52 days

Species	Threshold (°C)
European seabass, Dicentrarchus labrax	25
Gilthead seabream, Sparus aurata	24
Amberjack, Seriola dumerili	23
Atlantic Bluefin tuna, Thunnus thynnus	23
Japanese clam, Ruditapes decussatus	21
Blue mussel, Mytilus edulis	21
Manila clam, Rudtape philippinarum	20
Mediterranean mussel, Mytilus galloprovinciales	20

Figure 8.8. Number of days exceeding the fish thermal threshold.

Source: SOCLIMPACT project deliverable D4.3. Atlases of newly developed indexes and indicator.

8.3.3. Energy

A series of indicators related to renewable energy productivity is presented. The productivity and variability of these renewable energy sources will depend on climate. The possibility of reduced productivity due to climate change poses a risk to the energy generation, if it is based on these renewable energy sources. Also, a possible increase in the frequency and duration of solar and wind energy.

8.3.3.1. Percentage of days when T > 98th percentile - T98p

The T98p is defined as the percentage of time where the mean daily temperature T is above the 98th percentile of mean daily temperature calculated for the reference period 1986-2005.

For Madeira, we have conducted two separate analyses, as RCP2.6 was available for only one model, while for RCP8.5 we used four GCM/RCM pairs.

Thus, for one-model analysis, we find that for RCP2.6, the number of days with temperatures above the reference 98th percentile will exceed 10% by the end of the century. On the other hand, the RCP8.5 future projections with four models shows that, while in mid-century about 8% of the days will be above T98p threshold, at the end of the century, daily temperatures will be above T98p for almost 25% (~90 days per year) of time (see **Figure 8.9**).

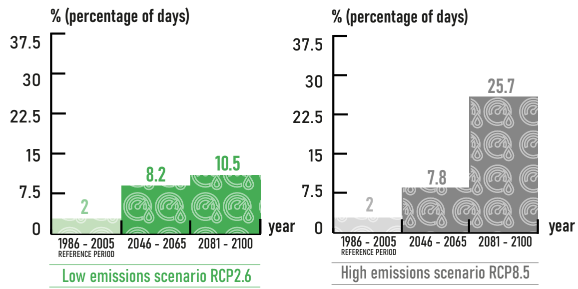


Figure 8.9. Percentage of days when T>98th percentile. Ensemble mean of MENA-CORDEX simulations.

Source: SOCLIMPACT project deliverable D4.3. Atlases of newly developed indexes and indicator.

8.3.3.2. Cooling Degree Days (CDD)

The Cooling Degree Days (CDD) index gives the number of degrees and the number of days that the outside air temperature at a specific location is higher than a specified base temperature, providing the severity of the heat in a specific time period, taking into consideration outdoor temperature and average room.

For Madeira, we have conducted two separate analyses, as RCP2.6 was available for only one model. Thus, for one-model analysis, we find that for near future, CDD will be three times larger at the end of the century. On the other hand, the analysis of the RCP8.5 future projections with four models, provide a more devastating picture as the number of CDD will be almost six times larger than the reference period (see **Figure 8.10**).

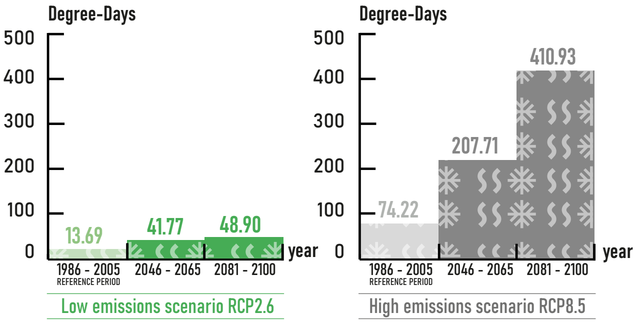


Figure 8.10. Cooling Degree Days. Ensemble mean of MENA-CORDEX simulations.

Source: SOCLIMPACT project deliverable D4.3. Atlases of newly developed indexes and indicator.

8.3.3.3. Standardized Precipitation Evapotranspiration Index (SPEI)

The Standardized Precipitation Evapotranspiration Index (SPEI) is used as an indicator of water availability. In particular, this hazard index can serve as a representative indicator for increases in water demand for islands' residents, tourists and agriculture, while it also provides an indication on the available water stored in dams or underground resources. In a drier future, which is the likely case for most islands, this will lead in additional increases in desalination and water pumping needs, a scenario which will substantially increase the cost for adaptation (see **Figure 8.11**).

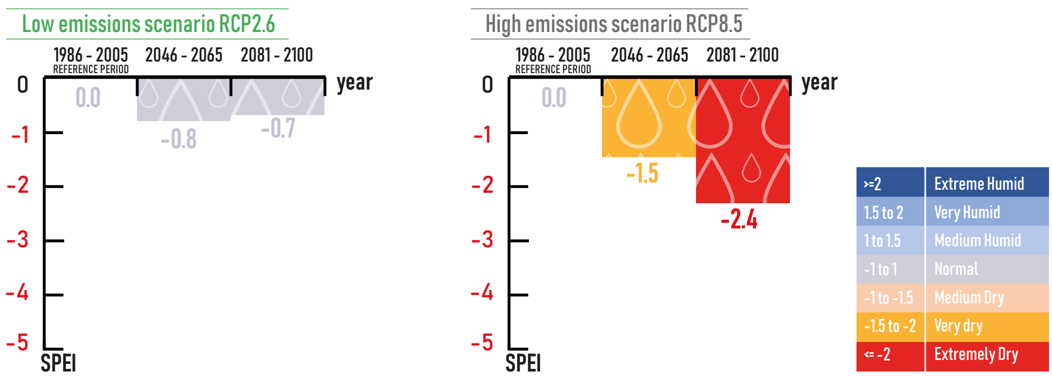


Figure 8.11. Standardized Precipitation Evapotranspiration Index (SPEI).

Source: SOCLIMPACT project deliverable D4.3. Atlases of newly developed indexes and indicator.

8.3.4. Maritime transport

8.3.4.1. Sea Level Rise (SLR)

Sea Level Rise (SLR) is one of the major threats linked to climate change. It would induce permanent flooding of coastal areas with a profound impact on society, economy and environment. Moreover, an increase in the mean sea level would result in a larger impact of coastal storms with the consequent increase of risk. The results are presented in terms of mean sea level rise. For Madeira, the SLR ranges from 27.27 cm (RCP2.6) to 74.72 cm (RCP8.5) at the end of the century (see **Figure 8.12**).

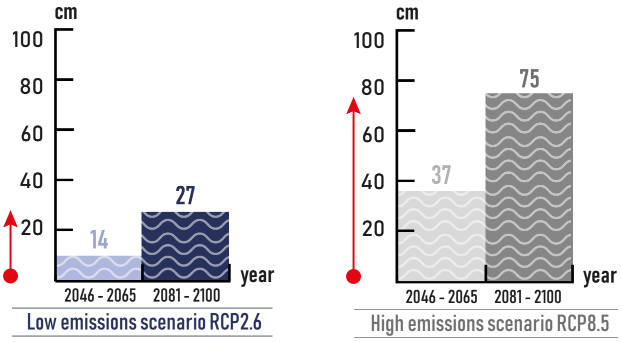


Figure 8.12. Mean sea level rise (in cm) with respect to the reference period (1986-2005). Own elaboration based on global and regional simulations.

Source: SOCLIMPACT project deliverable. D4.4b - Report on storm surge levels.

8.3.4.2. Wind extremes

The wind extremity index NWIX98 is defined as the number of days per year exceeding the 98th percentile of mean daily wind speed. This number decreases in the far future under RCP8.5 (- 32%).

Like the NWIX98, the 98th percentile of daily wind speed, WIX98, decreases under RCP8.5. with a more significant magnitude for RCP8.5 (see **Figure 8.13**).

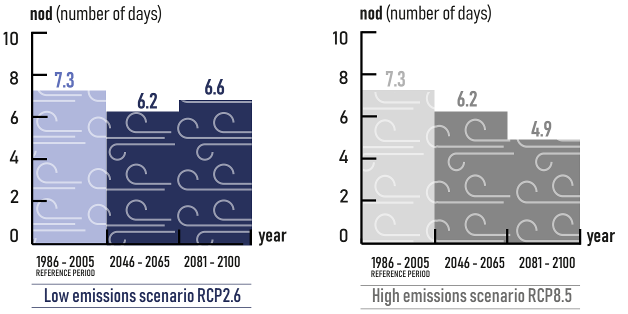


Figure 8.13. Wind Extremity Index (NWIX98). Ensemble mean of the MENA-CORDEX simulations.

Source: SOCLIMPACT project deliverable D4.3. Atlases of newly developed indexes and indicator.

8.3.4.3. Wave extremes (99th percentile of significant wave height averaged)

Marine storms can have a negative impact on maritime transport, coastal-based tourism and aquaculture, among other activities. To illustrate this impact, the 99th percentile of significant wave height averaged has been chosen. A decrease in the extreme wave height is found being larger under scenario RCP8.5 as illustrated in the following map. The more significant change is observed under RCP8.5. at the end of century with -5% (see **Figure 8.14**).

8.4. Risk Assessment

8.4.1. Tourism

8.4.1.1. Los of attractiveness due to increased danger of forest fires in touristic areas

For the reference period (1986-2005), the overall risk of forest fires is medium for Madeira. This is mainly due to the medium score of fire danger (hazard), the highest exposure (high population density and large forest areas) and medium vulnerability (medium flammability index). Nevertheless, in the near future (2046-2065) and distant future (2081-2100), whatever the considered RCP, the risk remains stable with an overall medium risk of forest fires over time. Despite being one of the archipelagos with the highest fire risk in the reference period, there is no change in the future for the category of risk, being surpassed by other archipelagos/islands that will have a higher fire risk (see **Figure 8.15** and **Figure 8.16**).

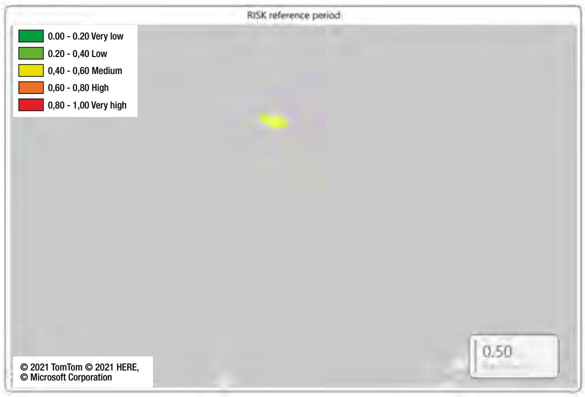


Figure 8.15. Risk score for the reference period.

Source: SOCLIMPACT Deliverable Report D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

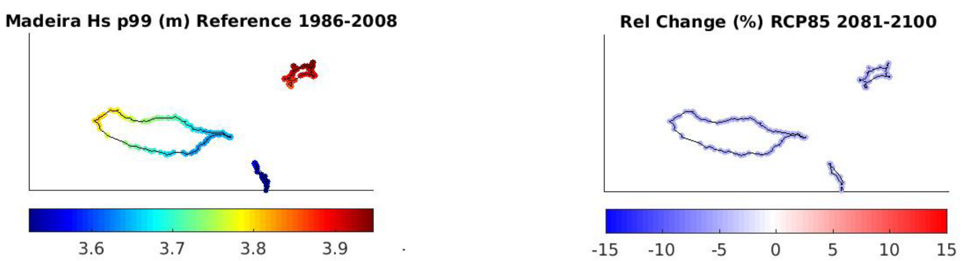


Figure 8.14. The 99th percentile of significant wave height averaged for the reference period and the relative change for the RCP8.5. Own elaboration based on global and regional simulations.

Source: SOCLIMPACT project deliverable D4.4b - Report on storm surge levels.

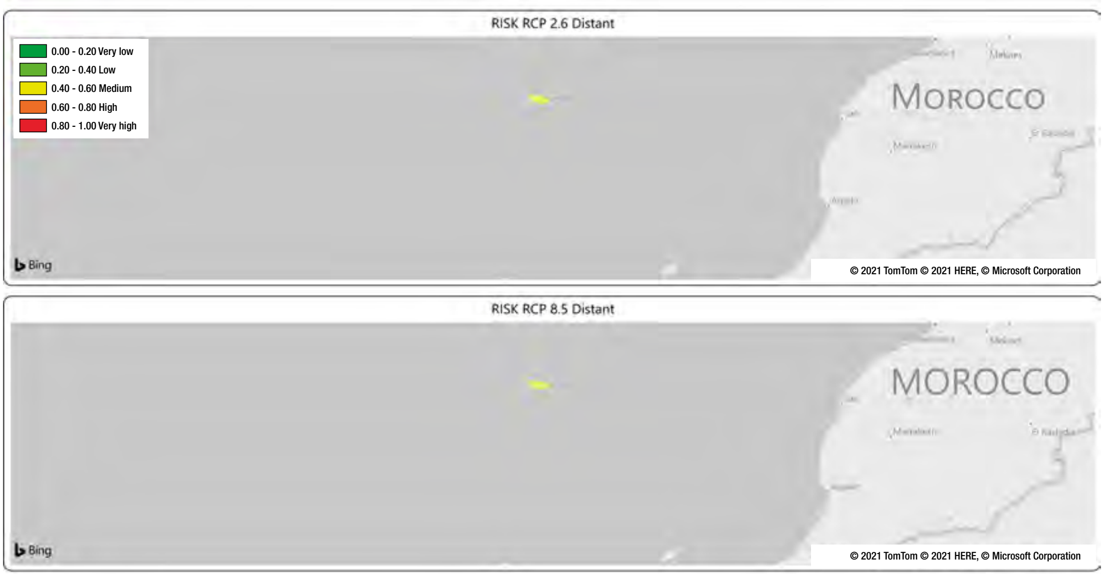


Figure 8.16. Risk score at the end in the distant future (2081-2100) under RCP2.6 (Ambitious Mitigation Policies) and RCP8.5 (Business as usual).

Source: SOCLIMPACT Deliverable Report D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

8.4.2. Aquaculture

8.4.2.1. Risk of increased fragility of aquaculture activity due to extreme weather events

For the Atlantic islands, uncertainties in the hazard components were too large to allow a reliable assessment, as shown in the following table. Two models are available (Hadley Centre and ACCESS) for data on return time. As can be seen in the table, the results of these models are highly variable. For Madeira, the risk in the future will be non-existent. Not considering probability, it could be concluded that climate change has not a negative or a positive effect on the occurrence on extreme events in Madeira. However, since this data cannot be considered accurate, more work needs to be done, in particular as to making higher-resolution reliable climate projections available for this area (see **Table 8.4**).

8.5. Impacts on the Blue Economy Sector

8.5.1. Tourism (Non-Market Analysis)

In order to analyse the reactions of tourists to the impacts of climate change and the preferences for adaptation policies, several hypothetical situations were posed to 252 tourists visiting Madeira whereby possible climate change impacts were outlined for the island (i.e., beach erosion, infectious diseases, forest fires, marine biodiversity loss, heat waves, etc.) (see **Figure 8.17**).

Firstly, tourists had to indicate whether they would keep their plans to stay on the island or find an alternate destination if the impact had occurred, which allows predictions of the effects on tourism arrivals to be made for each island. Secondly, tourists were asked to choose between various policy

Table 8.4. Risk results for the Atlantic Islands.

	Hadley centre			ACCESS		
	Reference period	**Mid century**	**End-century**	**Reference period**	**Mid century**	**End-century**
Risk	Historic	RCP 8.5	RCP 8.5	Historic	RCP 8.5	RCP 8.5
Azores	0.83	0.76	0.79	0.15	0.41	0.67
Madeira	0.20	0	0.01	0	0	0

Impact Chain: Extreme weather events – Integral normalized hazard for two Atlantic areas as predicted by two different downscaled global projections. Source: SOCLIMPACT Deliverable Report D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

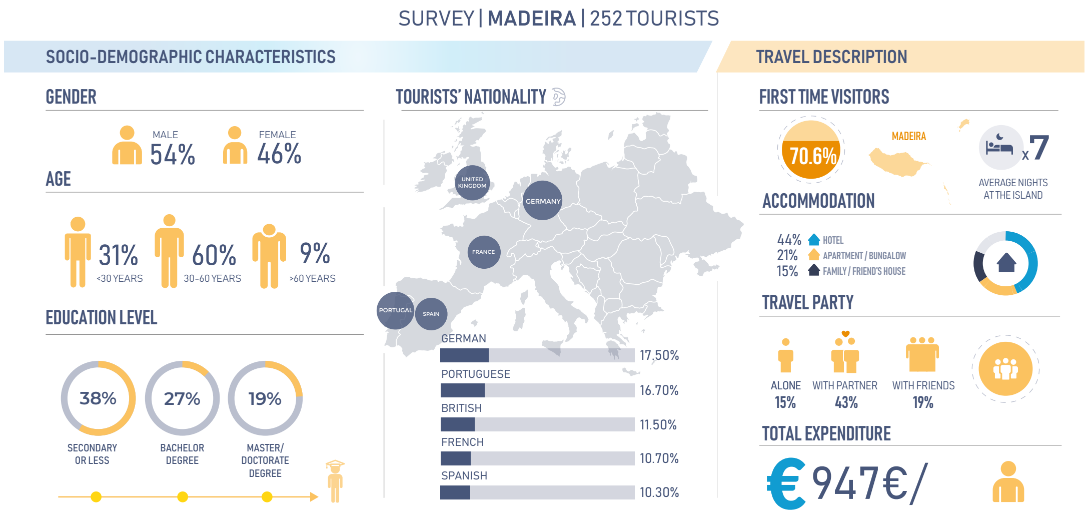


Figure 8.17. Socio-economic characteristics and travel description: tourists visiting Madeira.

Source: SOCLIMPACT Deliverable Report - D5.5. Report on market and non-market costs of Climate Change and benefits of climate actions for Europe.

measures funded through an additional payment per day of stay – the tourists' choices being an expression of their preferences for attributes/policies. To estimate the results, the conditional logit model was run by using the Stata software (see **Figure 8.18**).

In general, data confirms that tourists are highly averse to risks of infectious disease (84.90% of tourists would change destination). Moreover, they are not willing to visit islands where marine wildlife has disappeared to a large extent (80.2%) or where temperature becomes uncomfor-

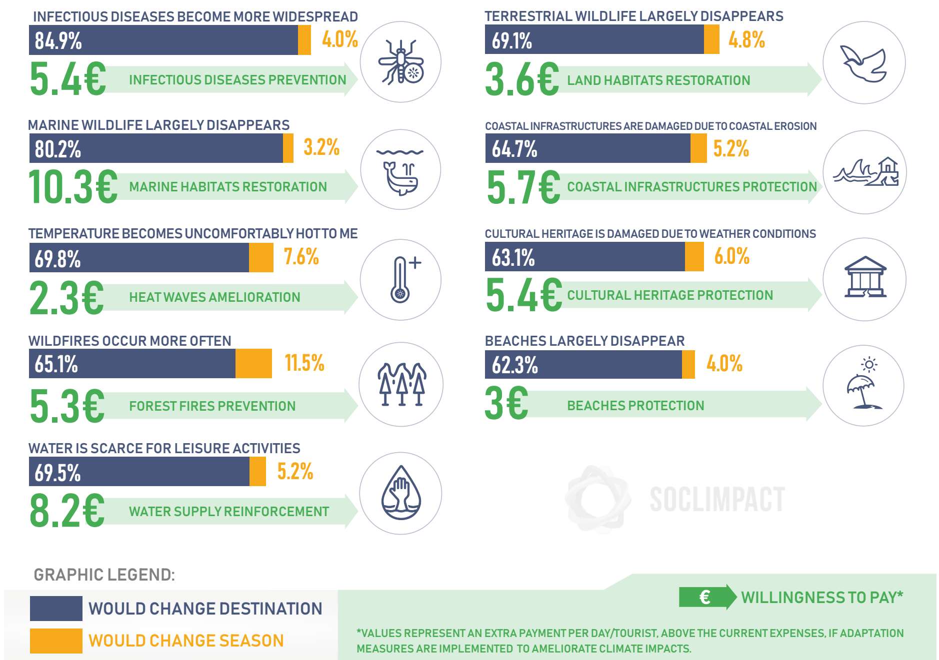


Figure 8.18. Tourists' response to climate change impacts and related policies: tourists visiting Madeira.

Source: SOCLIMPACT Deliverable Report - D5.5. Market and non-market analysis. Report on market and non-market costs of Climate Change and benefits of climate actions for Europe.

tably hot (69.8%). Consequently, policies related to marine habitat restoration (10.3€/day), water supply reinforcement (8.2€/day), and the prevention of infectious diseases (5.4€/day) are the most valued, on average, by tourists visiting this island.

Although climate change impacts are outside the control of tourism practitioners and policy-makers, they can nevertheless utilise this knowledge to improve the predictability of the effect that certain adaptation policies and risk management strategies, and develop their plans accordingly.

8.5.2. Aquaculture

The effects of increased sea surface temperatures on aquaculture production were calculated using a lethal temperature threshold by species, and considering the production share of the region. Four different future scenarios shown by IPCC estimations (RCP2.6 and RCP8.5 near and distant) were analysed, which correspond to four water temperature increases in the region (mean values), with respect to the reference period.

To do this, we assume that the total production of the region is Seabream (SB). A model of production function is calculated using the monthly biomass production which depends on the monthly water temperature. Results are presented on a yearly basis (mean values). In order to facilitate the interpretation of the results, we present the value of production of the last year available, for which we calculate the new values under the different climate change scenarios.

In both scenarios, the production function will not be negatively affected by the increased sea temperature, as the projected values are under the lethal threshold of the fish species (33 °C). There is only an apparent contradiction with the analysis provided in the previous section (risk assessment). While the risk analysis considered many other aspects of vulnerability and exposure, the analysis here only includes temperature and production, assuming that the rest of variables will not intervene (see **Figure 8.19**).

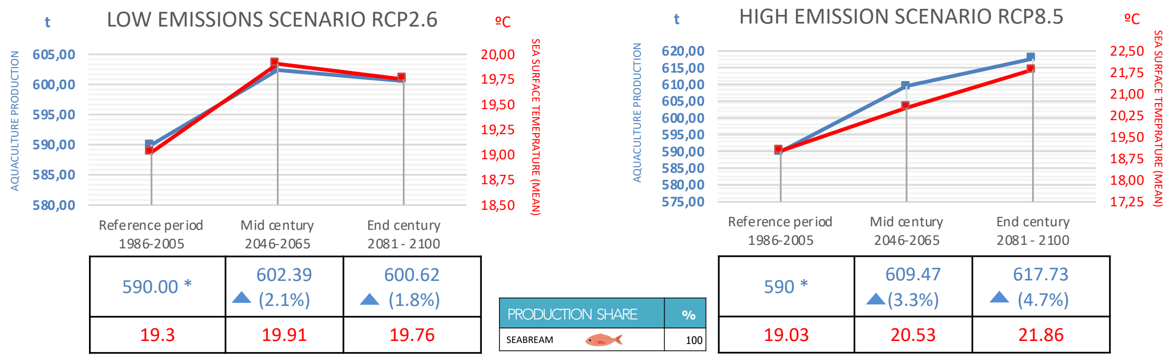


Figure 8.19. Estimations of changes in aquaculture production (tons), due to increased sea surface temperature.

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

8.5.3. Energy

Climate change may impose welfare reductions to the European islands' societies by affecting thermal comfort. Cooling Degree Days (CDD) are a measure of how much (in degrees), and for how long (in days), outdoor air temperature is higher than 21 °C. The CDD is used as a measure of the energy needed to cool buildings. The increase in CDD and the energy demand (GWh/year) for cooling are estimated for the islands under different scenarios of global climate change.

Under the high emissions scenario, it is expected that the CDD increase to almost 411 CDD. Under this situation, the increase in cooling energy demand is expected to be about 600% (see **Figure 8.20**).

The Standardized Precipitation Evapotranspiration Index (SPEI) is analysed as a representative indicator for increases in water demand for islands' residents, tourists and agriculture, while it also provides an indication on the available water stored in dams or underground resources. To estimate the increase of energy demand due to the increase in water demand, it was assumed that most of the islands will have to produce desalinated seawater (or groundwater) to meet further increases of demand. Thus, the estimation of the increase in energy demand (GWh/year) to produce more drinking water has been done based on the energy consumption required to desalinate seawater.

Under the low emissions scenario (RCP2.6), there are not significant changes in the SPEI indicator, that will remain in its "normal" level, as it is nowadays. Under RCP8.5, the scenario alerts on a severe aridity leading to an increase of 159% of the energy demand (see **Figure 8.21**).

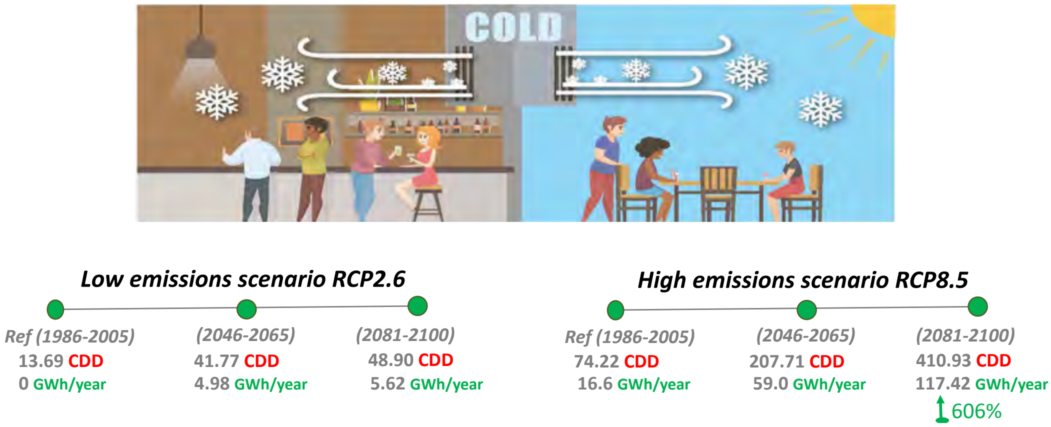


Figure 8.20. Estimations of increased energy demand for cooling in Madeira under different scenarios of climate change until 2100.

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

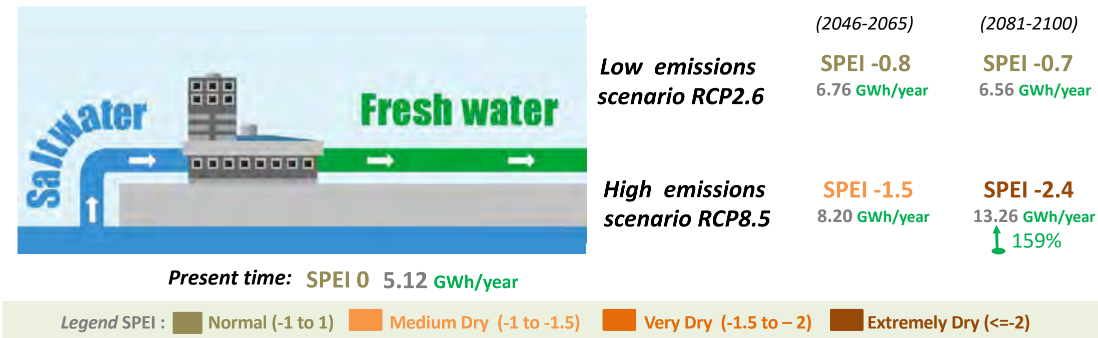


Figure 8.21. Estimations of increased energy demand for desalination in Madeira under different scenarios of climate change until 2100.

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

8.5.4. Maritime Transport

For maritime transport, it has been estimated the impact of Sea Level Rise on ports' operability costs of the island. The costs have been calculated with reference to 1 meter; that is, the investment needed to increase the infrastructures' height by 1 meter. There is not necessarily a strict correspondence between the SLR and the required elevation of port infrastructures, which also depends on the coastal hydrodynamic and the shape of dikes of each port. By experts' recommendation, we have assumed that 1 meter increase in port height is required to cope with the SLR under RCP8.5 scenario of emissions. Extrapolation for other RCP scenarios is then conducted based on proportionality.

The starting point was the identification of the principal ports on each island (economic relevance). Second, the analysis of the different port areas (exterior, ramps, oil, etc.), and their uses. Third, the elevation costs were estimated per each area and port separately (considering 1 meter elevation). Thus, the costs of 1 meter elevation presented are the sum of all areas and ports analysed, and including the rest of the ports of the island (if applicable) based on proportionality. Estimations consider that all ports areas of the entire zone should be elevated at the same time. In other words, the economic values can be interpreted as the depreciation (amortization) costs of the investment needed to increase all porsts' infrastructures' in the island for 125 years time horizon. No discount rate has been applied.

As expected, the rising of sea levels will affect the sector, as new investment will be needed to keep ports' operability. Under the high emissions scenario, it is expected that these costs could increase until 0.98 million euros per year until the end of the century (see **Figure 8.22**).

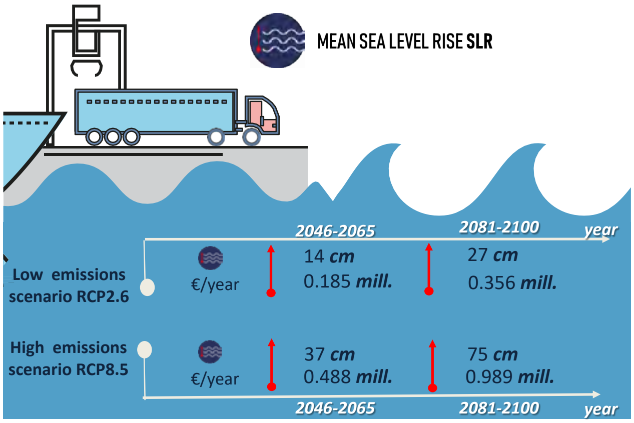


Figure 8.22. Increased costs for maintaining ports' operability in Madeira under different scenarios of SLR caused by climate change until 2100.

Source: SOCLIMPACT Deliverable Report D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

8.6. Impacts on the Island's Socio-Economic System

The aim of our study is to assess the socioeconomic impacts of biophysical changes for the island of Madeira. For this purpose, we have used the GEM-E3-ISL model, a single-region, multi-sectoral general equilibrium model based on the principles of neo-classical theory, and GINFORS, a macro-econometric model based on the principles of post-Keynesian theory.

Both models include 14 sectors of economic activity, with an emphasis on services and specifically on those composing the tourism industry. The GEM-E3-ISL model also includes endogenous representation of labor and capital markets as well as bilateral trade flows by sector.

Changes in the mean temperature, sea level and precipitation rates are expected to affect energy consumption, tourism flows and infrastructure developments. These impact-chains have been examined and quantified under two emission pathways: RCP2.6, which is compatible with a temperature increase well below 2 °C by the end of the century, and RCP8.5, which is a high-emission scenario. The impact on these three factors was used as input in the economic models, which then assess the effects on GDP, consumption, investments, employment, etc.

In total, 15 scenarios have been quantified for Madeira. The scenarios can be classified in the following categories:

1. Tourism scenarios: these scenarios examine the reduction in tourism revenues due to changes in human comfort as captured by the hum-index, the degradation of marine environment, the increased risk of forest fires and beach reduction. The aggregate tourism scenario (TOUR-SC6) assesses the economic impacts of a simultaneous change of all (the above-mentioned) factors.
2. Energy scenarios: the aggregate energy scenario (ENER-SC3) assessed the impacts on regional economic performance of increased total electricity demand driven by cooling and water desalination demand.
3. Infrastructure scenario: this scenario assesses the impact of port infrastructure damages (INFRA-MAR).
4. Aggregate scenarios: these scenarios examine the total impact of the previous-described changes in the economy.

In the aggregate scenario, we examine the impacts of a simultaneous change in electricity consumption, tourism revenues and infrastructure damages. The scenario specifications for the two climatic variants are presented below (see **Table 8.5**):

Table 8.5. Aggregate scenario –inputs.

	Tourism revenues (% change from reference levels)	Electricity consumption (% change from reference levels)	Infrastructure damages (% of GDP)
RCP2.6 (2045-2060)	-14.35	1.70	-0.20
RCP2.6 (2080-2100)	-17.02	41.10	-0.25
RCP8.5 (2045-2060)	-23.25	3.20	-0.54
RCP8.5 (2080-2100)	-27.37	8.40	-0.69

Source: SOCLIMPACT Deliverable Report D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

The theoretical and structural differences of the two models mean that this study produces is a reasonable range of impacts, given the uncertainty embodied in economic analysis and especially in the long-term.

In GEM-E3-ISL, the economy is in equilibrium at each point in time. Prices adjust to ensure that supply equals demand (market clearing), capital is fully used; however, the model allows for equilibrium unemployment as it takes into account labor market rigidities. The impacts are driven mainly by the supply side through changes in production costs which influence relative prices; hence, competitiveness and trigger substitution effects. The GEM-E3-ISL model assesses the impacts on the economy up to 2100.

The macro-econometric type of models, such as GINFORS, do not require that all markets are in equilibrium; idle capital and involuntary unemployment are some other features of this type of models where the results are driven mainly by adjustments in the demand side of the economy. The GINFORS assesses the impacts on the economy up to 2050.

With respect to GDP, the estimated change compared to the reference case is between -1.2% and -3.2% in the RCP2.6 in 2050, and between -2% and -4.0% in the RCP8.5. The cumulative change over the period 2040-2100 is estimated (by GEM-E3-ISL) to be equal to -3.4% in the RCP2.6 and -3.7% in the RCP8.5. Increased electricity needs are the most important driver of changes in the RCP2.6, while in the RCP8.5 GDP, changes are driven mainly by the tourism and infrastructure component (see **Figure 8.23**).

With respect to sectoral impacts, both models show a significant decrease in the activity of tourism related sectors and an increase in the activity of the manufacturing sector. The GINFORS also foresees increased activity in the primary production sectors and consumer goods while in the GEM-E3-ISL primary production increases only in the RCP2.6, while in the RCP8.5 the magnitude of changes leads to a decrease in their activity levels (see **Figure 8.24**).

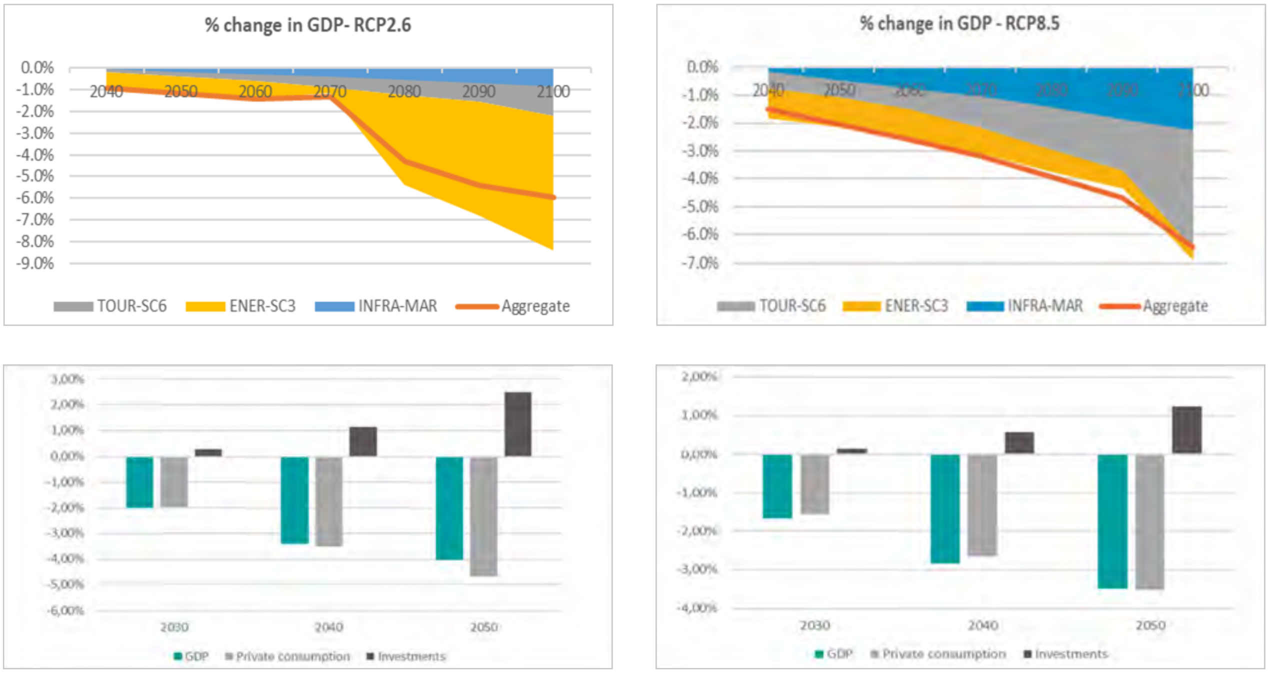


Figure 8.23. Percentage Change in GDP. GEM-E3-ISL results (above), GINFORS (below).

Source: own calculation.

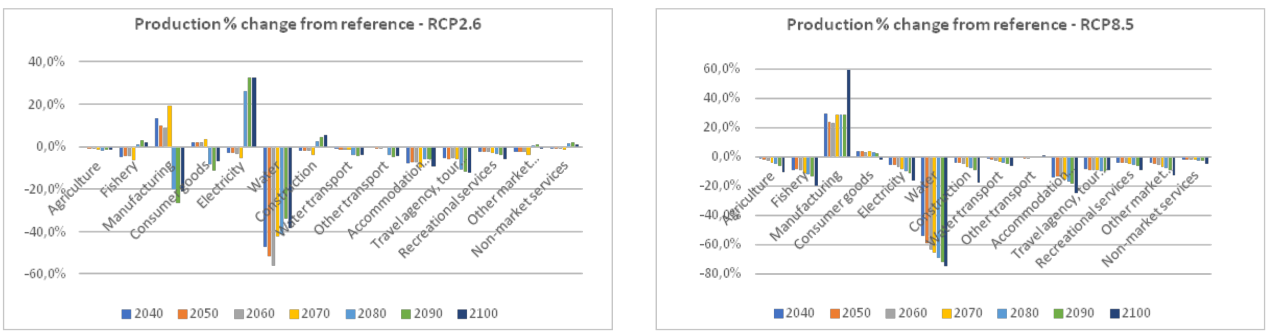


Figure 8.24. Production percentage change from reference. GEM-E3-ISL results.

Source: own calculation. ***(Continued on the next page)***

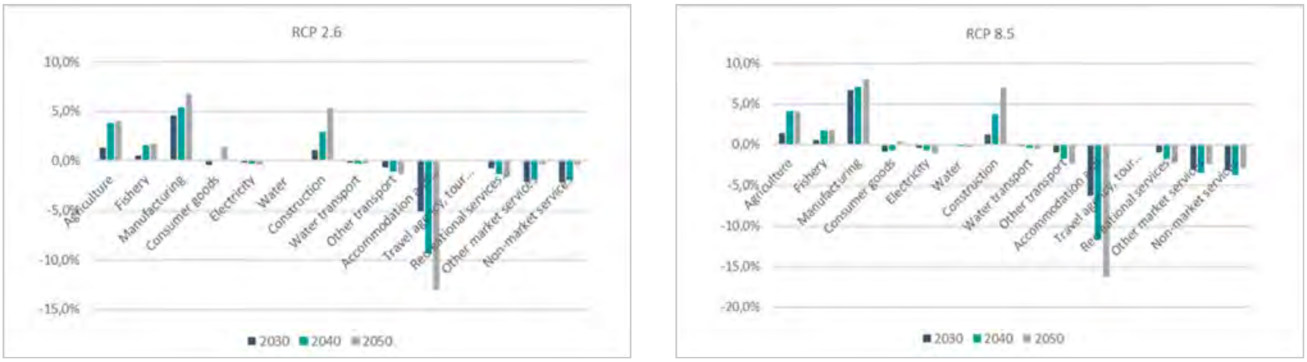


Figure 8.24 (Cont.). Production percentage change from reference. GINFORS results.

Source: own calculation.

Overall, employment falls in the economy and especially in tourism related sectors following the slowdown in domestic activity. In GEM-E3-ISL, increases in employment in non-tourism related activities are related to labor costs reductions (as wages fall and their competitiveness increases), which results in a substitution of capital with labor in other sectors as well as to competitiveness gains. Employment falls on average by 0.2 % in the RCP2.6 and by 0.6 % in the RCP8.5 driven by employment losses in the tourism industry (see **Figure 8.25**).

Figure 8.25. Employment percentage change from reference. GEM-E3-ISL results (above), GINFORS (below).

Source: own calculation.

8.7. Towards Climate Resiliency

The Autonomous Region of Madeira is a signatory to three commitments in the scope of climate change mitigation, the Under2 Memorandum of Understanding at a regional level, the Pact of Islands at an island level and the Covenant of Mayors, at a local level.

The Under2 Memorandum of Understanding (MOU) is a climate agreement for subnational governments. By signing the agreement on October 2017, the Autonomous Region of Madeira commits to achieve a 90 % reduction in CO_2 emissions until 2050, in comparison to 1990 – the level of emission reduction necessary to limit global warming to under 2 °C by the end of this century. Governments who sign or ratify the Under2 MOU become part of the Under2 Coalition, that is a global community of state and regional governments committed to ambitious climate action in line with the Paris Agreement.

The Pact of Islands signed by the Regional Government on April 2011 is an instrument where the island's authorities commit to go beyond the objectives set by the EU for 2020, reducing the CO_2 emissions in their respective territories by at least 20 %, contributing to the achievement of the sustainable goals of the European Union for the year 2020.

The mitigation actions to achieve the Pact of Islands commitment are stated in the Sustainable Energy Action Plans (SEAPs) that were developed by AREAM for Madeira and Porto Santo Islands under the ISLEPACT project, co-financed by DG TREN and *Empresa de Electricidade da Madeira* (EEM).

According to these plans, the future policies for energy will be oriented to ensure the security of energy supply, economic and environmental sustainability of the sector and quality of energy services, and to contribute to job creation, regional added value and competitiveness of the regional economy.

At a local level, SEAPs with local mitigation measures were also developed by AREAM for 9 municipalities under the project PACTO DE AUTARCAS, financed by the European Regional Development Fund (ERDF) and the Municipalities of Machico, Santana, São Vicente, Porto Moniz, Calheta, Ponta do Sol, Ribeira Brava, Câmara de Lobos and Porto Santo.

For 2030 and 2050, at regional and local levels, Sustainable Energy and Climate Action Plans (SECAPs) are being developed by AREAM for the Autonomous Region of Madeira and 7 municipalities, under Horizon 2020, in the scope of the C-TRACK 50 project, that will present mitigation and adaptation measures at regional and local levels. Concerning mitigation, the objective is, in relation with 1990, to reduce at least 40 % of emissions by 2030 and reach carbon neutrality in 2050 by reducing at least 85 % of emissions at local level combined with carbon sequestration.

The MADEIRA 2020 Regional Smart Specialization Strategy (RIS3) is also an important instrument that identifies the strategic areas for the Autonomous Region of Madeira, addressing different interactions with climate change mitigation and adaptation:

- Tourism;
- Sea resources and technologies;
- Health and wellness;
- Agri-food quality;
- Sustainability, maintenance and infrastructure management;
- Energy, mobility and climate change;
- Information and communication technologies.

Specifically concerning Adaptation, in September 2015, Madeira approved the Strategy CLIMA-Madeira - Climate Change Adaptation Strategy of the Autonomous Region of Madeira. This strategy aims to:

- Enhance the knowledge about the relationship between the climatic system and the natural and human systems;
- Reduce the vulnerability for the impacts of climate change;
- Explore the opportunities created by climate change;
- Promote adaptation measures based on evidences from scientific studies and good practices;
- Integrate the adaptation measures in the current governmental instruments;
- Promote the involvement and synergies among the stakeholders in the process of adaptation.

Several instruments are being developed to increase the adaptation capacity in order to reduce the risk of flash floods and forest fires. It should be noted that, in the last decade, several extreme climatic events have caused floods and forest fires with high gravity, namely:

- Flash flood on 20th February 2010: a heavy rain in the high peaks of Madeira caused a massive flash flood in Funchal and Ribeira Brava causing 47 victims, 250 wounded, 600 displaced people, and 217 million € in damages, affecting the commerce, public utility services (electric grid, water supply), infrastructures (roads and ports) and the tourism activity.
- Flash flood in Porto da Cruz on 28th and 29th November 2013: a heavy rain on the north coast of Madeira caused massive landslides that destroyed houses and roads in the town of Porto da Cruz.
- Fires on 18th July 2012: This fire burned several houses and forest area, displacing about 100 people.
- Fires 8-9th August 2016: This fire started in the forest area and reached the Funchal city centre causing 3 victims and 61 million € of damages in the city infrastructures with more than 300 buildings affected, displacing about 1000 people.

After the flash flood of 20th February 2010, the Madeira Alluvial Risk Assessment Study (EARAM1)[2] was developed, which allowed to assess and characterize the risks associated with this type of flood (alluvial), establishing the principles that should guide interventions against its effects and providing elements to justify the investments in the recovery of populations and infrastructures. EARAM1 proposes a set of guiding principles for protection measures, grouped and characterized in six types of actions:

- Retention of solid material;
- Control solid material transport;
- Vulnerability mitigation of exposed areas;
- Control of risk exposure;
- Forecast and warning - Structured forecast system;
- Training and information to the public.

In 2017, the Plan for the risk of flood management of the Autonomous Region of Madeira (PGRI-RAM 2016-2021) was developed with the following strategic objectives:

- Increase the perception of the risk of flooding and of the strategies of action in the population and social and economic agents;
- Improve the knowledge and the forecasting capacity to adequate the flood risk management;
- Improve spatial planning and exposure management in flooded areas;
- Improve resilience and decrease the vulnerability of elements located in the areas of possible flooding;
- Contribute to improving or maintaining the good condition of water bodies.

Madeira already has an early warning system of flash floods. It can predict a flash flood six hours in advance. The system's name is Flash Flood Alert Systems (SAARAM) and was developed by LREC – Laboratório Regional de Engenharia Civil.

Madeira is also developing the Regional Strategy Against Forest Fires (PRDFCI) that will be concluded by August 2020.

Concerning the financial resources to implement mitigation and adaptation measures stated in the existing planning instruments and studies, in addition to national, regional and local financial resources, the structural funds are a key resource.

The Regional Strategic Orientation Document Compromisso Madeira@2020 established the framework for the implementation of the structural funds during the 2014-2020 programming period. The document states that it is important to develop an upstream work to reinforce the knowledge about future and current events related to climate change, integrating international networks of research and sharing the knowledge and the good practices of intervention. In parallel, Compromisso Madeira 2020 underlines the need to develop approaches of interaction among different regional authorities (public health, tourism and leisure, water resources, coastal areas, agriculture, forests, etc.) to identify intervention measures that assure (Compromisso Madeira@2020 - Page 42 and 43):

- Implementation of preventive measures in the field of Civil Protection that contribute to the improvement of the population's quality of life, to its safety and assets;
- Dissemination of scientific knowledge and good practices of adaptation;
- Formulation of anticipatory measures to mitigate vulnerabilities and climate change effects;
- Elaboration of strategic and operational orientations for adaptation to climate change, on global and sectoral terms;
- Creation of an integrated information system that allows the development of databases and the indicators generation for the identification and prospective management of the main health risks related to climate change, e.g., floods (at coastal level and water courses), extreme temperatures, air and ozone pollution and vector-borne diseases.

In the current framework programme, several measures of mitigation and adaptation were implemented with structural funds, namely in the field of data collection, planning, risk assessment and management instruments, warning systems, and water and energy storage.

As part of the preparation for the next framework programme, the Madeira 2030 Strategic Orientation Document (version of October 2019) was prepared, in which, with a direct link to climate change, two of the region's strategic challenges stand out:

- Consolidation of regional value chains (Tourism / Leisure; Blue Economy; Knowledge Services; and Energy and Sustainable Mobility).
- Fostering innovative experiences in adapting to climate change and energy transition in crucial areas of water, soil, biodiversity and energy sources management, focusing on critical territories and valuing the creation of innovation and experimentation relationships with the priorities in regional smart specialization.

Within the scope of this challenge, the Autonomous Region of Madeira is equipped with recent sectoral planning instruments and others in the final phase (Integrated Strategic Transport Plan, Sustainable Urban Mobility Plan, Regional Agenda for the Circular Economy, CLIMA-Madeira Strategy, Sustainable Energy, Waste Management Plan, PROT RAM - first phase…) that identify specific priorities and action measures that should inspire public guidelines for strategic and operational management and allocation of public, national and regional public funding resources.

2 https://poseur.portugal2020.pt/media/41664/sistema-de-alerta-de-aluvi%C3%B5es-na-ram_srei.pdf

Specific limits and obstacles

Atlantic islands lie in very critical areas, where global models might be inaccurate in predicting the large scale patterns (regional models are not available), and resolution is so coarse that in fact many islands don't even exist in model orography. There are insufficient downscaled climate modelling results, which are not included in the MENA-CORDEX ensemble. For exmaple, there is a lack of high-resolution wave simulations comprising these Atlantic Islands, which limits the analysis of climate change impacts, being only possible to infer future tendencies. Stakeholders should be aware that uncertainty is an inherent characteristic of available climate projections, and that any future planning must cope with it.

There is also a lack of systematic data collection in different economic sectors. Also, specific historical climate data are missing, namely seawater temperature and waves. As a result, there is a reactive adaptation due to knowledge gaps. Therefore, one of the island's adaptation focus should be, first, the development of reliable information systems for the periodic monitoring of these components.

Other limitations can be summarized as follows:

- Funding mechanisms to overcome adaptation specificities associated to outermost condition;
- Adaptation strategy is not mainstream in all sectoral policies;
- Lack of economies of scale and small markets;
- Weather forecast constraints due to isolation and fragmentation of Atlantic Archipelagos, which limits prevention, preparedness and response performance to extreme weather events.

8.7.1. Policy Recommendations

A stakeholders consultation process was carried out in the island, aiming to propose, analyse and rank alternative adaptation measures for the island. This exercise provided the opportunity to create a multisectoral working group, with the participation of around 65 local and regional policy makers, public and private companies, research institutions, associations, and local experts, that had the possibility to increase their knowledge on climate change and adaptation. It is important to acknowledge the adaptation challenges in the daily decision-making process and in the sectoral and holistic planning exercises, and to update the regional adaptation strategy, foreseen for 2021.

The main aim of these meetings was:

1. Identify and present the characterized packages of adaptation and risk management options for the island.
2. Develop detailed integrated adaptation pathways, in three timeframes: Short term (up to 2030), Mid-century (up to 2050) and End-century (up to 2100).
3. Evaluate and rank adaptation options for 4 blue economy sectors in the island (energy, maritime transport, aquaculture and tourism).

Four scenarios of intervention were analysed, called Adaptation Policy Trajectories, which are different visions of future policy adaptation choices:

- APT A Minimum Intervention - Low investment, low commitment to policy change.
- APT B Economic Capacity Expansion - High investment, low commitment to policy change.
- APT C Efficiency Enhancement - Medium investment, medium commitment to policy change.
- APT D System Restructuring - High investment, high commitment to policy change.

It was assumed that adapting to climate change may range from minimal to high cost, and from requiring a small or incremental change to a significant transformation from the *status quo*. However, not all APT scenarios were considered in all islands, especially when their stakeholders had a clear vision on the types of measures with greatest viability. Therefore, the final set of proposed adaptation measures are framed in the islands' socio-economic and political context, have a sectoral perspective, and respond to the islands' future scenarios of climate change. At the same time, the involvement of regional stakeholders in policy design allows them to engage in the effective implementation of climate actions on their island.

In Appendices from K to N, a brief explanation of each adaptation option can be found, classified by type or class: Vulnerability Reduction, Disaster Risk Reduction, Social-Ecological Resilience, and Local Knowledge. The latest group refers to very specific measures proposed by stakeholders in each island to ratify the needs.

Reliable climate change projections are fundamental for the decision-making process on resources allocation for climate change adaptation. Until now, the decision-making process on climate change adaptation is highly linked with the occurrence of extreme weather events that have severe socioeconomic and environmental impacts. The allocation of high investments on Post-disaster recovery, in sequence of extreme weather events, reduces the capacity of investment on adaptation measures to increase resilience and decrease climate change vulnerability. This fact highlights the importance of reliable downscaling climate models for the Atlantic.

The EU outermost regions, particularly Atlantic Ocean archipelagos, have small and fragmented territories located on the margins of EU climate models, making it difficult to have reliable climate change projections. The participation in the project also highlighted the lack of systematic data collection that is important to enable downscaling of climate models and assess climate change impacts on natural ecosystems and infrastructures, as well as socio-economic activities.

Systematic data collection of diverse nature is crucial to regionalize the climate models and increase the accuracy of climate change projections and climate change impact assessment for the Autonomous Region of Madeira. Examples: series of data on seawater temperature and wave height at various coastal points, data on effects of heat waves on public health, record of number of visitors per age group, etc.

Adaptation policies based on scientific and technical knowledge instead of reaction to extreme weather events, allow to reduce socio-economic and environmental impacts of extreme weather events and other climate change impacts like water scarcity and heat waves by efficiently allocating available resources to increase resilience, decrease vulnerability and disaster risk, especially for risk mitigation, hazard preparedness and disaster response. This scientific based approach is particularly important to support adaptation policies to face climate change hazards never experienced before.

Particular attention of the EU to these specific territories is needed in order to have high-resolution climate models that provide reliable projections to support the planning and decision-making process on climate change adaptation. To overcome the lack of historic data series, EU regulations, guidelines, and funds for data collection to be reported to a centralized EU database could provide the necessary incitement for regional and local policy makers to allocate human and financial resources for data collection procedures.

Even considering a scenario with increased resolution on climate change modelling and climate change impact assessment, small and fragmented island territories, such as the Archipelago of Madeira, face greater uncertainty and error in weather forecasts and projections due to less coverage of weather observation networks (there are no fixed weather stations on the ocean, some data are collected by merchant vessels at sea). Even with a radar, which was installed after the flash floods of 2010, weather forecast is dependent on the presence of water or dust in the atmosphere. This disadvantage of small island territories, in relation to continental regions, should be considered by the Member States and by the EU, as the allocation of resources for climate change adaptation in these territories need to deal with a greater redundancy to tackle uncertainty.

Awareness raising and training of technicians and decision--makers on the issue of climate change and adaptation is important to foster cooperation between sectors with synergies, and to facilitate the integration of climate change variables namely data collection and processing, planning exercises, technical specifications of projects, prioritization of measures and allocation of funds.

Another conclusion of this exercise for Madeira archipelago was the evidence of the need for a specific adaptation approach to each island, as they have specificities that will determine different vulnerabilities to climate change. For example, Porto Santo Island, which joined the UNESCO world network of biosphere reserves in 2020, is highly dependent on seasonal tourist activities relying on its natural heritage, a 9 km sandy beach that, according to the project climate projections, 90% of its area will disappear by the end of the century. This underlines the importance of dune restauration and rehabilitation and beach nourishment as priority adaptation measures for Porto Santo Island, which is not a priority for Madeira Island, that has pebble beaches along the majority of its coastline. In Madeira, the increase in average temperature, heat waves episodes and reduction of precipitation will raise forest fire vulnerability of natural ecosystems, such as the Laurissilva Forest classified as UNESCO natural world heritage, an important asset for the island's tourism nature-based activities. Precipitation reduction will also affect, in Madeira Island, the water canal system that provides water for human consumption, irrigation and energy production and storage, and supports tourism nature-based activities in the water canal trails. This is a unique reality of Madeira Island that requires a specific adaptation approach.

8.7.1.1. Tourism

The regional priority to address Vulnerability Reduction was "Financial incentives to retreat from high-risk areas" for the APT B (Economic Capacity Expansion) for the medium term and for the APT D (System Restructuring) for all time frames, while the measure Economic Policy Instruments (EPIs) was considered a priority for the APT B for the short and long terms.

The regional priority for the APT A for all time frames (Minimum Intervention) was "Public awareness programmes". For the APT B and APT C (efficiency enhancement) for the medium and long term, and for the APT D for all time frames, the measure "Activity and product diversification" was consider the regional priority. This result reveals the stakeholder's perception that it is necessary invest more money and more political commitment to diversify the tourism economy instead of promoting awareness campaign.

Under the APT C, the regional priority was "Local circular economy" for all time frames. This measure will allow Madeira to decrease its waste and offers a framework to reduce CO_2 emissions from imports and exports. "Water restrictions, consumption cuts and grey-water recycling" was also considered a clear priority for all time frames for the APT C and the APT D. This measure will allow Madeira to use hydric resource more efficiency and decrease water waste.

For the short term, the measure "Beach nourishment" was consider the regional priority. For the medium and long term, the measure "Desalination" was considered the regional priority. This choice underlines the stakeholder concerns regarding the precipitation decrease projections and subsequent water scarcity.

For Disaster Risk Reduction, the measure considered a priority to address risk mitigation for the APT's A, B, and D was "Coastal protection structures" in the majority of the time frames, in opposition to the measure "Drought and water conservation plans", which was the priority for the short and medium term, for the scenario of Efficiency Enhancement.

Another clear regional priority for all time frames was "Mainstreaming Disaster Risk Management (DRM)" for the Efficiency Enhancement scenario, where the measures were available. In the scope of disaster response, the priority at short and medium terms was the measure “Fire management plans”, in coherence with the foreseen fire weather index that will stay in the same fire danger class (which is high). For the long term, the regional priority was “Health care delivery systems”, for Minimum Intervention scenario, in coherence with the foreseen significant increase of heat waves.

Another measure considered a priority by the stakeholders was “River rehabilitation and restoration” for all time frames for the APT B and APT C. This underlines the high risk of flash floods and its historic occurrence in Madeira island, and presence of dunes only in the small island of Porto Santo. Under cultural services, for all time frames for the APT C, there is a clear priority for “Adaptive management of natural habitats”, a key asset for the archipelago’s touristic activities.

Local Knowledge priorities where focused on habitats rehabilitation, conservation and monitoring actions, including control of non-indigenes species, that are important to increase ecosystems resilience to climate change, in order to preserve habitats, biodiversity and landscape, key assets for tourism, agriculture, fisheries and food security.

The diversification of economic activities was also considered a regional priority to reduce the dependence from tourism activities that can be disrupted by extreme weather events. Stakeholders recognise the importance of diversify the island economy by promoting the development of primary sector activities to increase food security and reduce food carbon footprint and promote digital innovative products and services. Also, fair trade, quality, certification, and differentiation can increase competitiveness of islands cash crops (see **Table 8.6**).

Table 8.6. Proposed adaptation options for tourism in Madeira.

<table>
<tr><td rowspan="7">APT A – Pathway
—
Minimum Intervention
low investment, low commitment to policy change
—
This policy trajectory assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td colspan="3">Public awareness programmes</td></tr>
<tr><td>Drought and water conservation plans</td><td colspan="2">Coastal protection structures</td></tr>
<tr><td colspan="2">Fire management plans</td><td>Health care delivery systems</td></tr>
<tr><td>Pre-disaster early recovery planning</td><td>Post-disaster recovery funds</td><td>Pre-disaster early recovery planning</td></tr>
<tr><td>Monitoring, modelling and forecasting systems</td><td>Adaptation of groundwater management</td><td>Monitoring, modelling and forecasting systems</td></tr>
<tr><td>Rehabilitation and conservation of islands natural habitats</td><td>Control measures for terrestrial and maritime tourist activities</td><td>Increase knowledge and modelling tools on climate change</td></tr>
<tr><td rowspan="8">APT B – Pathway
—
Economic Capacity Expansion
high investment, low commitment to policy change
—
This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td>Economic Policy Instruments (EPIs)</td><td>Financial incentives to retreat from high-risk areas</td><td>Economic Policy Instruments (EPIs)</td></tr>
<tr><td>Public awareness programmes</td><td colspan="2">Activity and product diversification</td></tr>
<tr><td>Beach nourishment</td><td colspan="2">Desalination</td></tr>
<tr><td colspan="3">Coastal protection structures</td></tr>
<tr><td>Monitoring, modelling and forecasting systems</td><td>Adaptation of groundwater management</td><td>Monitoring, modelling and forecasting systems</td></tr>
<tr><td colspan="3">River rehabilitation and restoration</td></tr>
<tr><td>Rehabilitation and conservation of islands natural habitats</td><td>Diversification of economic activities to reduce the dependence from tourism</td><td>Implement waste reduction and management procedures</td></tr>
<tr><td rowspan="10">APT C – Pathway
—
Efficiency Enhancement
medium investment, medium commitment to policy change
—
This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td>Public awareness programmes</td><td colspan="2">Activity and product diversification</td></tr>
<tr><td colspan="3">Local circular economy</td></tr>
<tr><td colspan="3">Water restrictions, consumption cuts and grey-water recycling</td></tr>
<tr><td colspan="2">Drought and water conservation plans</td><td>Coastal protection structures</td></tr>
<tr><td colspan="3">Mainstreaming Disaster Risk Management</td></tr>
<tr><td colspan="2">Monitoring, modelling and forecasting systems</td><td>Adaptation of groundwater management</td></tr>
<tr><td colspan="3">River rehabilitation and restoration</td></tr>
<tr><td colspan="3">Adaptive management of natural habitats</td></tr>
<tr><td>Rehabilitation and conservation of islands natural habitats</td><td>Increase knowledge and modelling tools on climate change</td><td>Implement waste reduction and management procedures</td></tr>
</table>

Table 8.6 (Cont.). Proposed adaptation options for tourism in Madeira.

<table>
<tr><th rowspan="8">APT D – Pathway
—
System Restructuring
high investment, high commitment to policy change
—
This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems</th><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td colspan="3">Financial incentives to retreat from high-risk areas</td></tr>
<tr><td colspan="3">Activity and product diversification</td></tr>
<tr><td colspan="3">Water restrictions, consumption cuts and grey-water recycling</td></tr>
<tr><td>Drought and water conservation plans</td><td colspan="2">Coastal protection structures</td></tr>
<tr><td colspan="2">Pre-disaster early recovery planning</td><td>Post-disaster recovery funds</td></tr>
<tr><td colspan="2">Monitoring, modelling and forecasting systems</td><td>Adaptation of groundwater management</td></tr>
<tr><td>Diversification of economic activities to reduce the dependence from tourism</td><td>Rehabilitation and conservation of islands natural habitats</td><td>Implement waste reduction and management procedures</td></tr>
</table>

Vulnerability Reduction *Disaster Risk Reduction* *Socio-Ecological Resilience* *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

8.7.1.2. Maritime transport

A priority to address Vulnerability Reduction for the scenario Capacity Expansion (APT B) was "Insurance mechanisms for ports" for all time frames, which is coherent with the low commitment to significant policy change. For the scenario System Restructuring (APT D), the priority measure considered was "Financial incentives to retreat from high-risk areas" for all time frames, which is coherent with a scenario of high level of investment and high commitment to significant policy change.

Another regional priority for the APT A, B, C and D was "Awareness campaigns for behavioural change" for the short term. For the medium and long terms, in all scenarios, the regional priority was "Social dialogue for training in the port sector", underling the concerns with the foreseen sea level rise in these time frames.

Under the APT C, the regional priority was "Climate resilient economy and jobs" for all time frames, which underlines the importance to reduce imported goods from the exterior. Under the APT C and D, in all time frames, the measure "Restrict development and settlement in low-lying areas" was also considered a priority.

"Sturdiness improvement of vessels" was selected by 50% of the stakeholders at the short term for the APT B. The measure "Increase operational speed and flexibility in ports" was considered the priority for the medium and long term.

For Disaster Risk Reduction, "Climate proof ports and port activities" was consider a priority for the APT A for all time frames, for the APT B for the medium and long term, for the APT C for the medium term and for the APT D for the short and medium term, this underlines the island dependence from the exterior and the importance of preventing the disruption of port activities due extreme weather events.

In Social-Ecological Resilience adaption objective, the measure "Marine life friendly coastal protection structures" was selected for the short term for the APTs A, B, C and D. This recognizes the potential role of coastal protection infrastructures for biodiversity preservation. For the medium and long term, the selected measure "Combined protection and wave energy infrastructures" was selected for the APTs B, C and D, which indicates the potential contribution of wave energy for islands energy independence.

Under cultural services, there is a priority to "Integrate ports in urban tissue" for short and long term for the APT C. For the medium term, the measure "Ocean pools" was consider the regional priority.

The Local Knowledge measure "Increase knowledge and modelling tools on climate change for islands" was considered a priority for the short term for all scenarios, which highlights the importance of this measure for the decision-making process.

During the results discussion, the stakeholders underlined the concerns related with the sea level rise that will require high investments in all ports and coastal protection infrastructures. Prepare island ports to supply alternative fuels was identified as an important contribute to reduce the island energy dependence and the emissions associated with maritime transport.

It was also underlined the importance of making available climate change projections on maximum hight waves that combined with the sea level rise will have severe impacts in ports, marines, and other coastal infrastructures.

Given the high dependence from maritime transport, it was highlighted by the stakeholders the importance of backup routes and infrastructures to overcome the islands isolation during extreme weather events which require high investment, justified by the principle of territorial continuity.

The maritime transport is very important for the transportation of goods and persons in archipelagos, being highlighted by the stakeholders that the next concession for maritime public transport services between islands should have requirements concerning alternative fuels and improved vessels sturdiness to increase climate change resilience.

The regional stakeholders mention the importance to increase the regional dry docks areas in marines and shipyards to protect recreational and maritime touristic activities boats in extreme weather events (see **Table 8.7**).

Table 8.7. Proposed adaptation options for maritime transport in Madeira.

Pathway	Short-term (up to 2030)	Mid-century (up to 2050)	End-of-century (up to 2100)
APT A – Pathway — **Minimum Intervention** low investment, low commitment to policy change — This policy trajectory assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts	Awareness campaigns for behavioural change	Social dialogue for training in the port sector	
	Climate proof ports and port activities		
	Prepare for service delays or cancellations	Intelligent Transport Systems (ITS)	
	Backup routes and infrastructures during extreme weather		
	Marine life friendly coastal protection structures		Combined protection and wave energy infrastructures
	Increase knowledge and modelling tools on climate change	City ports as coastal protection infras-tructures against extreme climate events	Specific requirements to increase climate change resilience
APT B – Pathway	**Short-term (up to 2030)**	**Mid-century (up to 2050)**	**End-of-century (up to 2100)**
— **Economic Capacity Expansion** high investment, low commitment to policy change — This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy	Insurance mechanisms for ports		Financial incentives to retreat from high-risk areas
	Awareness campaigns for behavioural change	Social dialogue for training in the port sector	
	Sturdiness improvement of vessels	Increase operational speed and flexibility in ports	
	Consider expansion/retreat of ports in urban planning	Climate proof ports and port activities	
	Marine life friendly coastal protection structures	Combined protection and wave energy infrastructures	
	Coastal protection structures	Hybrid and full electric ship propulsion	Coastal protection structures
	Specific requirements to increase climate change resilience	City ports as coastal protection infras-tructures against extreme climate events	Prepare islands ports to supply alternative fuels and electricity
APT C – Pathway	**Short-term (up to 2030)**	**Mid-century (up to 2050)**	**End-of-century (up to 2100)**
— **Efficiency Enhancement** medium investment, medium commitment to policy change — This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system	Awareness campaigns for behavioural change	Social dialogue for training in the port sector	
	Climate resilient economy and jobs		
	Restrict development and settlement in low-lying areas	Refrigeration, cooling and ventilation systems	Restrict development and settlement in low-lying areas
	Consider expansion/retreat of ports in urban planning	Climate proof ports and port activities	Consider expansion/retreat of ports in urban planning
	Reinforcement of inspection, repair and maintenance of infrastructures	Early Warning Systems (EWS) and climate change monitoring	
	Marine life friendly coastal protection structures	Combined protection and wave energy infrastructures	
	Coastal protection structures	Hybrid and full electric ship propulsion	
	Integrate ports in urban tissue	Ocean pools	Integrate ports in urban tissue
	Increase knowledge and modelling tools on climate change	Specific requirements to increase climate change resilience	City ports as coastal protection infras-tructures against extreme climate events
APT D – Pathway	**Short-term (up to 2030)**	**Mid-century (up to 2050)**	**End-of-century (up to 2100)**
— **System Restructuring** high investment, high commitment to policy change — This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems	Financial incentives to retreat from high-risk areas		
	Awareness campaigns for behavioural change	Social dialogue for training in the port sector	
	Restrict development and settlement in low-lying areas		
	Climate proof ports and port activities		Consider expansion/retreat of ports in urban planning
	Backup routes and infrastructures during extreme weather		Post-disaster recovery funds
	Marine life friendly coastal protection structures	Combined protection and wave energy infrastructures	
	Increase knowledge and modelling tools on climate change	Specific requirements to increase climate change resilience	City ports as coastal protection infrastructures against extreme climate events

Vulnerability Reduction *Disaster Risk Reduction* *Socio-Ecological Resilience* *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

8.7.1.3. Energy

"Financial support for buildings with low energy needs" was considered a priority for the short term. At medium and long term, the regional priority was "Financial support for smart control of energy in houses and buildings", which reflects an expected maturity of these solutions.

"Green jobs and businesses" was another priority selected by stakeholders for all time frames, as well as "Small scale production and consumption (prosumers)".

In opposition to "Seawater Air Conditioning (SWAC)", the measure "Demand Side Management (DSM) of Energy", was consider a priority in all time frames of the APT B (Economic Capacity), where the measure was available. This choice is compatible with sea water average temperature and the island orography that difficult the sea access.

For Disaster Risk Reduction, the measure considered a priority to address risk mitigation for the APT's A, B, C and D was "Review building codes of the energy infrastructure" in the majority of the time frames, in opposition to the measure "Upgrade evaporative cooling systems", which was the priority, at the long term, for the scenarios of Economic Capacity Expansion (APT B), Efficiency Enhancement (APT C) and System Restructuring (APT D).

Under the class hazard preparedness, the priority at short term was "Early Warning Systems (EWS)", and for the medium and long terms the priority was "Grid reliability" for the Efficiency Enhancement scenario, where the measures were available.

In the scope of disaster response, the priority at short term was the measure "Study and develop energy grid connections", and for the medium and long term the regional priority was "Energy-independent facilities (generators)", for minimum intervention scenario.

Under the post disaster recovery, the measure "Energy recovery microgrids" was considered a priority for all time frames in the APT D, and for the short and medium terms in the APT A, in opposition to the measure "Local recovery energy outage capacity" that was consider a priority at long term for the APT A.

In social-ecological resilience adaption objective, the region gave clear priority to "Energy efficiency in urban water management" for all time frame in the APT A (Minimum Intervention), APT B (Economic Capacity Expansion), APT C (Efficiency Enhancement) and APT D (System Restructuring). This measure considered a priority the creation of "Urban green corridors" for all time frames for the APT B and for the medium term for the APT C. The local stakeholders recognize the importance of reducing the air temperatures in the cities without increasing the consumption of energy for cooling and improving the quality of life in open spaces.

Local Knowledge priorities were focus on minimize islands energy dependence from imported fossil fuels to increase its climate change resilience in all time frames of the 4 scenarios. It highlights the importance to decrease imported fossil fuels as a climate change adaptation measure. The following priority is related with the diversification of energy supply and electricity generation, which contributes the measure "Promote electric mobility integrated in smart grids with smart-charging and vehicle-to-grid infrastructure" and "Implement electricity prices for renewable energy generation on islands based on actual local costs to stimulate the RES generation".

During the results discussion, the stakeholders underlined the importance of the diversification on energy supply and electricity generation for energy independence of islands, as the extreme weather events, namely storms, can destroy wind farms, being important to invest in photovoltaic energy and the foreseen precipitation reduction will affect hydropower production. Hydro energy will be affected by water scarcity and by priority uses, human consumption and irrigation in Madeira island.

It was also underlined that downscaling the climate models for Madeira and Porto Santo islands is important to better forecast the renewable resources and deal with the foreseen reduction of precipitation. Currently, the available climate data and models for these Atlantic islands do not have the necessary accuracy to support the decision-making process on RES and energy storage investments (see **Table 8.8**).

Table 8.8. Proposed adaptation options for the energy sector in Madeira.

APT A – Pathway — **Minimum Intervention** low investment, low commitment to policy change — This policy trajectory assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts	**Short-term (up to 2030)**	**Mid-century (up to 2050)**	**End-of-century (up to 2100)**
	Public information service on climate action	Green jobs and businesses	Public information service on climate action
	Review building codes of the energy infrastructure		
	Study and develop energy grid connections	Energy-independent facilities (generators)	
	Energy recovery microgrids	Local recovery energy outage capacity	
	Energy efficiency in urban water management		
	Minimize islands energy dependence from imported fossil fuels	Implement electricity prices for renewable energy	Diversification on energy supply and electricity generation

Table 8.8 (Cont.). Proposed adaptation options for the energy sector in Madeira.

<table>
<tr><td rowspan="9">APT B – Pathway
—
Economic Capacity Expansion
high investment, low commitment to policy change
—
This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy</td><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td>Financial support for buildings with low energy needs</td><td colspan="2">Financial support for smart control of energy in houses and buildings</td></tr>
<tr><td colspan="3">Green jobs and businesses</td></tr>
<tr><td colspan="3">Demand Side Management (DSM) of Energy</td></tr>
<tr><td>Review building codes of the energy infrastructure</td><td colspan="2">Upgrade evaporative cooling systems</td></tr>
<tr><td colspan="3">Energy efficiency in urban water management</td></tr>
<tr><td colspan="3">Urban green corridors</td></tr>
<tr><td>Diversification on energy supply and electricity generation</td><td>Minimize islands energy dependence from imported fossil fuels</td><td>Promote electric mobility integrated in smart grids</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="11">APT C – Pathway
—
Efficiency Enhancement
medium investment, medium commitment to policy change
—
This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system</td><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td>Public information service on climate action</td><td colspan="2">Green jobs and businesses</td></tr>
<tr><td colspan="3">Small scale production and consumption (prosumers)</td></tr>
<tr><td colspan="3">Energy storage systems</td></tr>
<tr><td>Review building codes of the energy infrastructure</td><td colspan="2">Upgrade evaporative cooling systems</td></tr>
<tr><td>Early Warning Systems (EWS)</td><td colspan="2">Grid reliability</td></tr>
<tr><td colspan="3">Energy efficiency in urban water management</td></tr>
<tr><td>Biomass power from household waste</td><td>Urban green corridors</td><td>Biomass power from household waste</td></tr>
<tr><td colspan="3">Educational garden plots</td></tr>
<tr><td>Minimize islands energy dependence from imported fossil fuels</td><td>Diversification on energy supply and electricity generation</td><td>Promote electric mobility integrated in smart grids</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="8">APT D – Pathway
—
System Restructuring
high investment, high commitment to policy change
—
This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems</td><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td colspan="3">Financial support for buildings with low energy needs</td></tr>
<tr><td colspan="3">Green jobs and businesses</td></tr>
<tr><td colspan="3">Energy storage systems</td></tr>
<tr><td colspan="2">Review building codes of the energy infrastructure</td><td>Upgrade evaporative cooling systems</td></tr>
<tr><td colspan="3">Energy recovery microgrids</td></tr>
<tr><td colspan="3">Energy efficiency in urban water management</td></tr>
<tr><td>Promote electric mobility integrated in smart grids</td><td>Minimize islands energy dependence from imported fossil fuels</td><td>Diversification on energy supply and electricity generation</td></tr>
</table>

Vulnerability Reduction · *Disaster Risk Reduction* · *Socio-Ecological Resilience* · *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

8.7.1.4. Aquaculture

"Awareness campaign and behavioural change" was considered a priority for all time frames, which indicates the necessity of this measure on a scenario of low political commitment. Under APT D (System Restructuring), the considered priority was "Efficient feed management" for all time frames, which is coherent with a scenario of high political commitment.

The measure "Short-cycle aquaculture" was considered a priority for all time frames for the APT C and on short for the APT D. Currently, "Integrated multi-trophic aquaculture (IMTA)" is not implemented in Madeira island. This measure was selected for the medium and long-time frame for APT D, being the priority consistent with a system restructuring scenario.

The measure "Submersible cages" was also considered a clear priority in all time frames for the scenario where the measure was available, that is, Economic Capacity Expansion scenario. This measure enables to submerge the cages according with temperature gradient and to protect them from sea storms, being considered a good adaptation measure. Furthermore, it decreases the cages visual impact, which, currently, is one of the main regional social constraints to the development of this blue economy sector.

In the scope of disaster response, the priority for the short term was the measure "Mainstreaming Disaster Risk Management (DRM)" and for the medium and long term the regional priority considered was "Contingency for emergency management, early harvest and/or relocation", for Minimum Intervention scenario.

Under the post disaster recovery , the region gave priority to the measure "Recovery Post-disaster plans" for all time frames in the APT A, and in the short term for the APT D, in opposition with the measure "Recovery-disaster funds", that is a priority for the medium and long terms for the APT D (high investment/ high commitment).

In Social-Ecological Resilience adaption objective, the region gave priority to the measure "Feed production" for all time frames in the scenarios Minimum Intervention (APT A) and Economic Capacity Expansion (APTB), both scenarios with low commitment. This measure was a priority in the APT C and APT D at short term, being the measure "Species selection" the priority measure at medium and long term for these APTs.

Local Knowledge priorities where focus on "Aquaculture as an alternative to fishing" on all time frames for the lower commitment scenarios, APT A and APT B, and at short term in the efficiency enhancement scenario, APT C. It highlights the role of aquaculture in the preservation of the natural resources. The following priorities are related with circular economy and self-sufficiency in aquaculture, which is important to the regional food security and decrease the region dependence from the exterior. They are strategic objectives to increase the archipelago resilience to climate change.

The measure "Long-term environmental data collection and management" at regional level was also considered a priority in the APT A, C and D, which is important to ensure the reduction of the aquaculture impacts and increase its social acceptability (see **Table 8.9**).

Table 8.9. Proposed adaptation options for the aquaculture sector in Madeira.

<table>
<tr><td rowspan="8">APT A – Pathway
—
Minimum Intervention
low investment, low commitment to policy change
—
This policy trajectory assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td>Awareness campaigns for behavioural change</td><td colspan="2">Efficient feed management</td></tr>
<tr><td colspan="3">Risk-based zoning and site selection</td></tr>
<tr><td>Mainstreaming Disaster Risk Management</td><td colspan="2">Contingency for emergency management, early harvest and/or relocation</td></tr>
<tr><td colspan="3">Recovery Post-disaster plans</td></tr>
<tr><td colspan="3">Feed production</td></tr>
<tr><td colspan="2">Aquaculture as an alternative to fishing</td><td>Long-term environmental data collection and management</td></tr>
<tr><td rowspan="8">APT B – Pathway
—
Economic Capacity Expansion
high investment, low commitment to policy change
—
This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td colspan="2">Financial schemes, insurance and loans</td><td>Tax benefits and subsidies</td></tr>
<tr><td colspan="3">Awareness campaigns for behavioural change</td></tr>
<tr><td colspan="3">Submersible cages</td></tr>
<tr><td colspan="3">Climate proof aquaculture activities</td></tr>
<tr><td colspan="3">Feed production</td></tr>
<tr><td colspan="3">Selective breeding</td></tr>
<tr><td>Implementation of local sanitary programs at regional scale</td><td>Aquaculture as an alternative to fishing</td><td>Implement measures for increasing local industry self-sufficiency</td></tr>
<tr><td rowspan="10">APT C – Pathway
—
Efficiency Enhancement
medium investment, medium commitment to policy change
—
This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td colspan="2">Efficient feed management</td><td>Awareness campaigns for behavioural change</td></tr>
<tr><td>Promote cooperation to local consumption</td><td colspan="2">Addressing consumer and environmental concerns at the local level</td></tr>
<tr><td colspan="3">Short-cycle aquaculture</td></tr>
<tr><td>Risk-based zoning and site selection</td><td colspan="2">Climate proof aquaculture activities</td></tr>
<tr><td colspan="3">Disease prevention methods</td></tr>
<tr><td>Feed production</td><td colspan="2">Species selection</td></tr>
<tr><td colspan="2">Best Management Practices</td><td>Selective breeding</td></tr>
<tr><td>Promote aquaculture cuisine</td><td colspan="2">Create educational visits</td></tr>
<tr><td>Aquaculture as an alternative to fishing</td><td>Aquaculture and circular economy</td><td>Implement measures for increasing local industry self-sufficiency</td></tr>
<tr><td rowspan="8">APT D – Pathway
—
System Restructuring
high investment, high commitment to policy change
—
This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td>Financial schemes, insurance and loans</td><td colspan="2">Tax benefits and subsidies</td></tr>
<tr><td colspan="3">Efficient feed management</td></tr>
<tr><td>Short-cycle aquaculture</td><td colspan="2">Integrated multi-trophic aquaculture</td></tr>
<tr><td>Risk-based zoning and site selection</td><td colspan="2">Climate proof aquaculture activities</td></tr>
<tr><td colspan="3">Recovery Post-disaster funds</td></tr>
<tr><td>Feed production</td><td colspan="2">Species selection</td></tr>
<tr><td>Implement measures for increasing local industry self-sufficiency</td><td>Aquaculture and circular economy</td><td>Long-term environmental data collection and management</td></tr>
</table>

Vulnerability Reduction · *Disaster Risk Reduction* · *Socio-Ecological Resilience* · *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

Chapter 9
Malta

SOCLIMPACT

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 776661

CONTENTS

Malta at a Glance

The country of Malta refers to a group of islands in the Mediterranean Sea, with a total surface of 316 km^2 (Zammit, 1986). The three largest islands, Malta, Gozo and Comino, host all 515,000 residents (NSO, 2020). The low, rocky islands can be identified by their coralline limestone and steep coastal cliffs. Sandy beaches cover small parts of the coastline. The highest point of the islands is Ta' Dmejrek on Malta Island, with an altitude of 253 m. The Maltese Islands do not have any permanent surface water and some rivers only spring during extreme rainfall. The islands have to deal with a shortage of fresh water and depend on desalination (FAO, 2006).

The Blue Economy Sectors

- **Aquaculture**

  Aquaculture is defined as "Farming finfish, shellfish and aquatic plants" (EC, 2020). It is one of the world's fastest growing food sectors and provides the planet with about half of all the fish we eat. The world's population is expected to rise to 9 billion by 2050, creating a considerable demand for food and sources of protein (World Bank, 2013). Aquaculture can contribute to assure food security, meet nutrition needs, as well as social and economic inclusion, employment and lessen the need for fish imports in some countries. Sustainable aquaculture is also needed because fisheries alone will not meet the growing demand for seafood (EC, 2015). In the context of islands, the aquaculture sector needs attention as it represents an important sector for many islands.

  Malta has 7 marine aquaculture operators, of which most are focused on tuna fattening and one operates a closed-cycle seabream farm. The farms are spread over 9 different sites. The annual production in 2018 was over 19,000 T, of which 90% was tuna (NSO, 2019a). Effects of increasing sea temperature and shifts in currents and nutrient flow may have an impact on the aquaculture sector. Especially since Malta's aquaculture sector is highly dependent on wild caught Tuna fisheries, an endangered species vulnerable to the effects of climate change.

- **Maritime Transport**

  Maritime transport has been a catalyst of economic development and prosperity throughout the history of the country. Malta has two mayor ports, the Malta Freeport in the Bay of Marsaxlokk, and the Port of Valletta. More than 90% of all goods entering and leaving Malta go through these ports (Malta Marittima, 2020). The port of Marsaxlokk is the base of 70% of the county's fishing fleet and is handling about 2.7 million Twenty-Foot Equivalent (Malta Freeport, 2020; TM, 2020). The Port of Valletta is a multi-purpose port equipped for a large number of maritime services such as cruise liner and cargo berths, bunkering facilities, ship building yards and storage facilities (Malta Marittima, 2020).

- **Energy**

  Malta uses a total of 180,000 Tons of fossil fuel per year and produces 133,419 MWh of renewable energy of which 58 MWh is wind energy, 125,054 MWh solar energy and 8,307 MWh produced using biogas (NSO, 2017). For a large part of its fossil fuel, it is dependent on Sicily. The Government strongly considers the exploration of blue renewable energy opportunities. The four main blue energy areas that are being focused upon for further study are: offshore wind farms, floating photovoltaic islands, tidal wave energy conversion and blue geothermal renewable energy.

- **Tourism**

  Tourism is one of the most important sectors for the Maltese economy contributing to approximately 27% of the GDP (World Travel and Tourism Council, 2018). Tourists are visiting Malta for the island's rich history and culture as well as aquatic activities. Lately, medical tourism has also become popular in Malta. In 2019, Malta had 2,753,239 visitors, an increase of 5.9% compared to 2018. Malta can accommodate 55,597 tourists at any given time with an occupancy rate of around 80% in summer and 47% in the winter months (MTA, 2019). The average stay is 7 nights, and the most popular time of the year is June to September. Most tourists are from the United Kingdom, followed by Italy, France, and Germany. Malta also has a significant number of visits from cruise liners (over 300 cruise liners/year) (MTA, 2019).

9.1. Current Climate and Risks

Malta has a typical Mediterranean climate with mild rainy winter and dry hot summers. The mean temperature for the summer months is 35°C, while the lowest average monthly temperature is 11°C in winter. The presence of the surrounding water mass shapes the climate of the Maltese islands significantly. The general weather is often cooler and more humid (75% average) compared to larger inland areas.

CURRENT CLIMATE-RELATED RISKS

- Coastal flood Medium

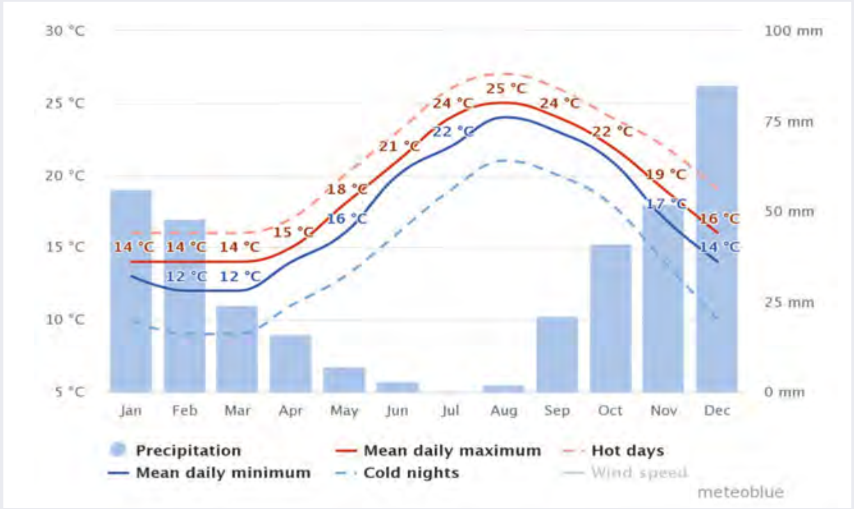
SIGNIFICANT CLIMATE EVENTS

- Storm (October 2018)
- Snowfall (December 2014)

The high thermal capacity of the sea provides a more stable ambient temperature on the islands. However, when colder air comes from the north at the end of summer, combined with the warmer waters, this creates weather instability causing heavy thunder storms and intense rainfall. One of the highest in Europe, Malta has an average of 3,000 hours of sun per year. The average sea water temperature is 20 °C. In the current government, climate change policy falls under the portfolio of the Minister for Sustainable Development, Environment and Climate Change (MSDEC) (see **Figure 9.1**).

CLIMATE CHARACTERISTICS (35.9°N 14.51°E, 90m asl)

Average temperature and precipitation



Wind speed

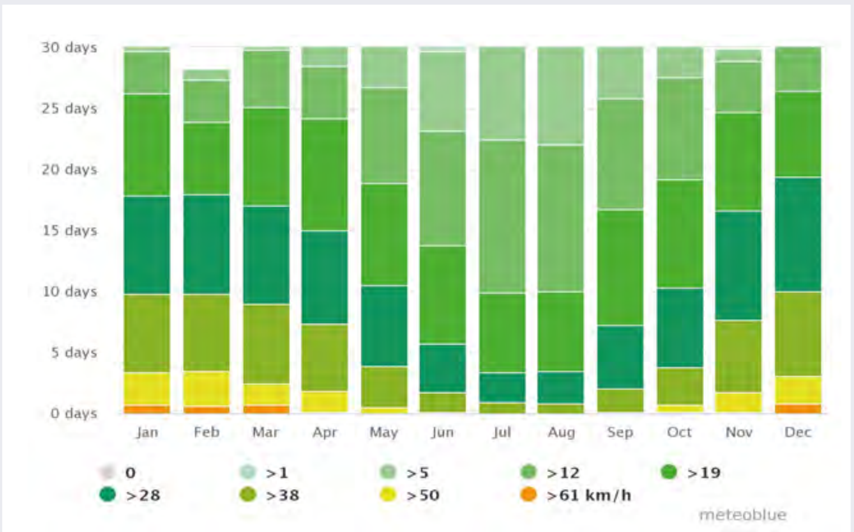
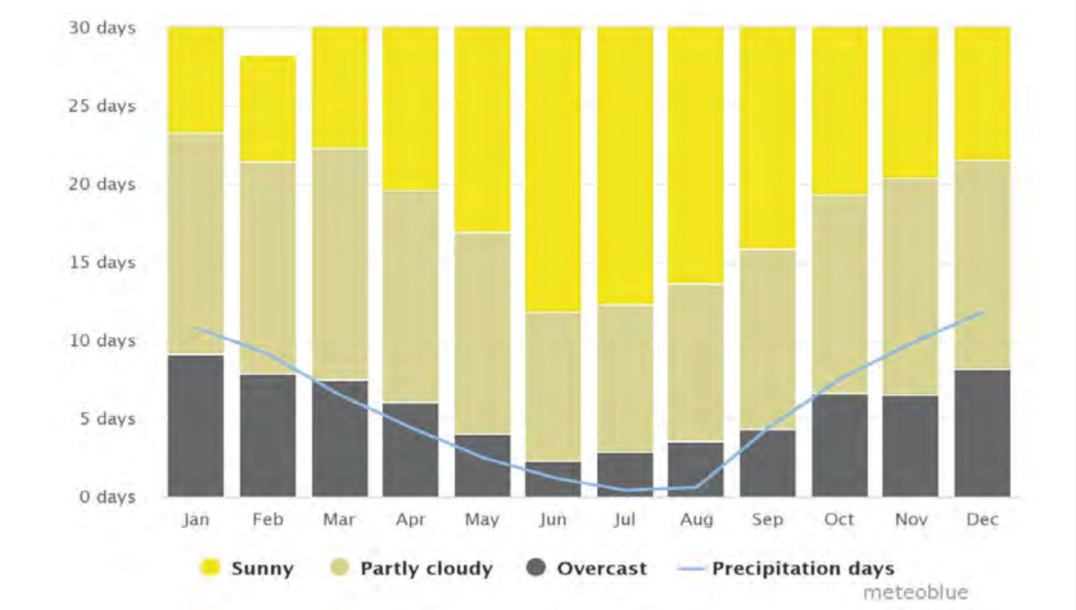


Figure 9.1. Climate factsheet.

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System). ***(Continued on the next page)***

Cloudy, sunny and precipitation



Wind rose

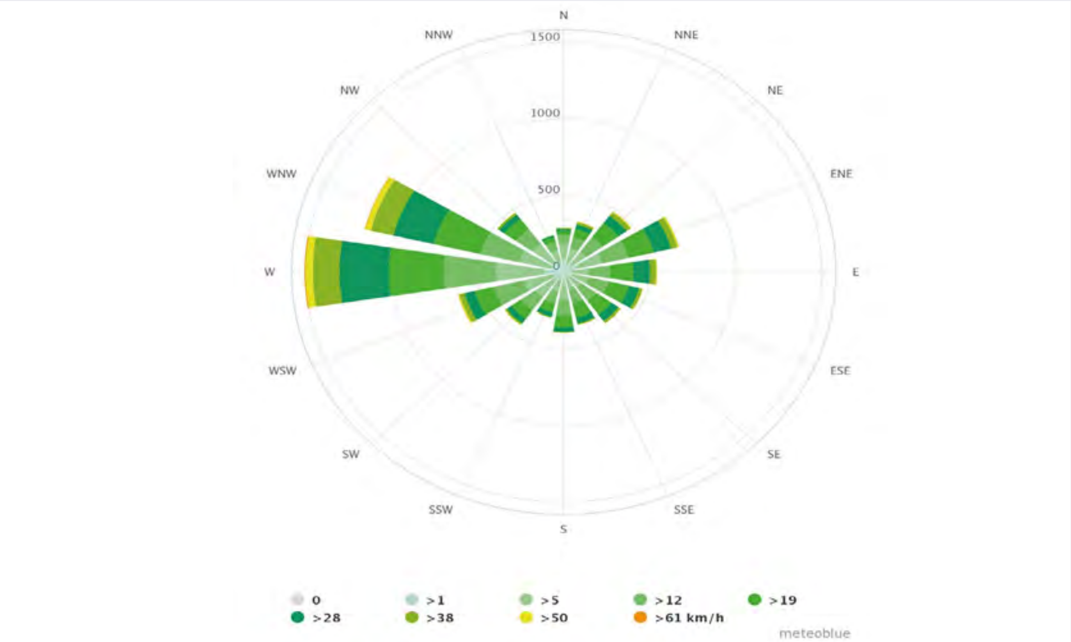


Figure 9.1 (Cont.). Climate factsheet.

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System).

9.2. Macroeconomic Projections

Malta registers a 1.7% annual GDP growth rate throughout the 2015-2100 period and a 1.8% rate in the 2015-2050 period. The main driver of growth during the short-term period is private consumption, which includes tourism demand. As seen in Figure 9.2, the contribution of private consumption in GDP increases throughout time to the detriment of investments and trade. Private consumption growth rates surpass that of GDP throughout the period, indicating that the Maltese economy is achieving growth through high value-added sectors like services and tourism but without investing further on productive capacity and adequate infrastructure.

In parallel, trade balance remains positive yet gradually becomes neutral. Tourism maintains a stable share in GDP throughout the period, which as discussed above is one of the highest in the Mediterranean. This also justifies the increasing share of private consumption in GDP. It is assumed that the GDP share of public consumption remains roughly the same throughout the 2015-2100 period, as Malta has already a privatized economy (see **Figure 9.2**).

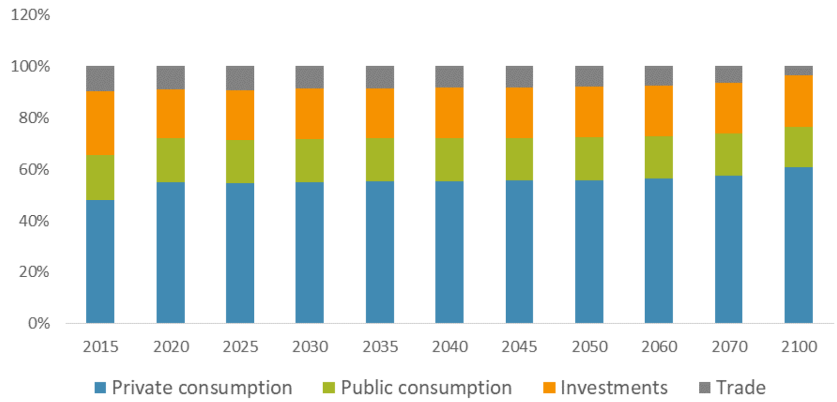


Figure 9.2. Macroeconomic components as a% share of GDP for Malta in 2015-2100.

SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

9.2.1. The Sectoral Projections

The Maltese economy remains a service-led economy throughout the 2015-2100 period with an increasing contribution of recreational, accommodation and other market services. Moving towards the end of the century, the share of primary and secondary sectors in gross value-added falls significantly to the benefit of sectors with higher value added, as observed in recent years. Blue growth sectors increase in importance throughout the 2015-2100 period. Tourism sustains or slightly increases its share in GDP throughout the period[1]. Similarly, water transport maintains its share (0.5% of GDP) while fisheries (which includes aquaculture) and electricity gradually see a lower contribution to gross value added (see **Figure 9.3** and **Table 9.1**).

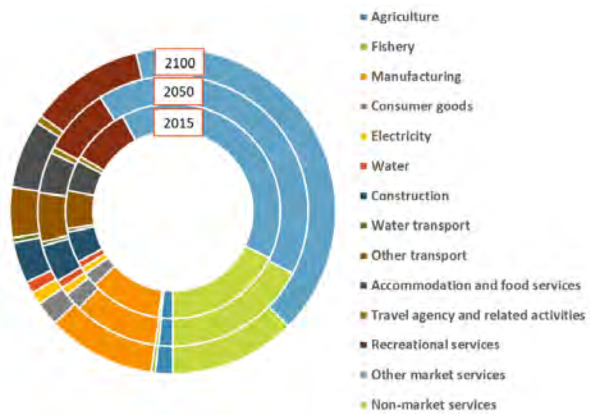


Figure 9.3. Sectoral value added as a% share to total GVA for Malta in 2015, 2050 and 2100.

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

[1] The share of tourism in GDP is calculated via the tourism satellite account (TSA) matrices of 2015, assuming that the same shares that indicate the contribution of tourism to the productions of tourism-related sectors (such as the accommodation and food services, transport services, travel agency and related activities, cultural and recreational activities) remain throughout the 2015-2100 period. Please, see Appendix B of SOCLIMPACT Deliverable Report D6.2 for the complete data-base of the estimated TSAs.

Table 9.1. Sectoral contribution as a% share of total gross value added for Malta in 2020-2100.

GVA% shares	2015	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
Agriculture	1.8%	1.9%	1.8%	1.7%	1.6%	1.7%	1.7%	1.7%	1.8%	1.8%	1.7%
Fishery	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
Manufacturing	10.8%	9.8%	9.7%	9.6%	9.7%	10.1%	10.1%	10.1%	10.6%	10.6%	10.8%
Consumer goods	2.1%	2.1%	2.0%	2.0%	2.1%	2.1%	2.1%	2.1%	2.2%	2.3%	2.4%
Electricity	1.0%	0.9%	0.9%	0.9%	1.0%	1.0%	1.0%	1.0%	1.1%	1.1%	1.3%
Water	1.1%	0.9%	0.9%	0.9%	1.0%	1.0%	1.0%	1.0%	1.1%	1.1%	1.2%
Construction	4.7%	4.2%	4.3%	4.3%	4.3%	4.5%	4.5%	4.5%	4.5%	4.4%	4.1%
Water transport	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Other transport	5.8%	6.1%	6.2%	6.2%	6.1%	5.9%	5.9%	5.9%	5.6%	5.5%	5.0%
Accommodation and food services	4.6%	4.5%	4.4%	4.3%	4.7%	4.8%	4.9%	4.9%	5.6%	5.9%	6.8%
Travel agency and related activities	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%
Recreational services	8.7%	7.2%	7.0%	6.8%	8.2%	7.8%	7.9%	8.0%	9.3%	9.7%	11.4%
Other market services	40.0%	41.9%	42.3%	42.6%	41.7%	41.6%	41.7%	41.7%	40.7%	40.8%	41.1%
Non-market services	17.8%	18.8%	18.9%	19.0%	18.0%	18.0%	17.7%	17.4%	15.9%	15.2%	12.5%

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

9.2.2. Employment

Malta already registers sustainable unemployment levels and the continuous growth of the service sectors leads to even lower unemployment rates towards the end of the century. The non-market services is a labour-intensive sector, thus contributing with a higher proportion to total employment than the respective share in total value added. Tourism-related and other market services are also large employers, while manufacturing and other transport sectors retain their shares throughout the 2015-2100 period. Tourism is the largest employer of the Blue growth sectors under analysis, particularly due to the high labour intensity of accommodation and food services, while water transport, fisheries and electricity all contribute with shares less than 0.5% (see **Table 9.2** and **Figure 9.4**).

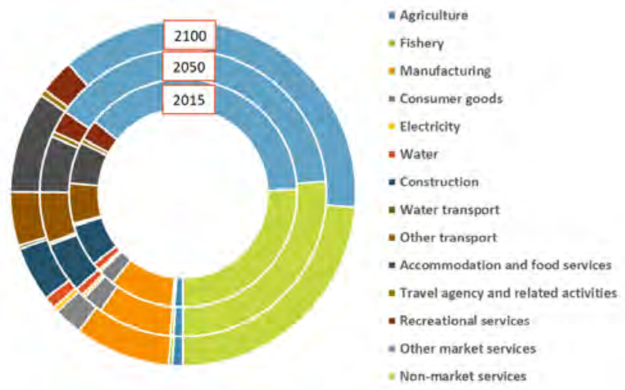


Figure 9.4. Sectoral employment as a% share of total for Malta in 2015, 2050, 2100.

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

Table 9.2. Unemployment rate in Malta in 2015-2100: own calculations.

	2015	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
Unemployment rate	5.4%	4.2%	4.2%	4.1%	4.1%	4.0%	4.0%	4.0%	3.9%	3.9%	3.8%

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

9.3. Climate Change Outlook

Climate hazards indicators represent the entry point to understand the climate change exposure of the blue economy sectors. The indicators have been computed for two scenarios, RCP2.6 (low emission scenario) and RCP8.5 (high emission scenario) and for different horizon times namely: a reference period (1965-2005), mid-century (2046-2065) and end of century (2081-2100). Main source of climate projections (future climate) for Malta is MED-CORDEX ensemble (regional scale of Mediterranean area) and CMIP5 ensemble (global scale) even if other model sources were applied when required, depending on available scales. Results are presented in form of maps, tables or graphs and only when the information shows an interesting outcome.

9.3.1. Tourism

9.3.1.1. Seagrass evolution

Posidonia Oceanica is a foundation species in Mediterranean waters. Foundation species have a large contribution towards creating and maintaining habitats that support other species. First, they are numerically abundant and account for most of the biomass in an ecosystem. Second, they are at or near the base of the directional interaction networks that characterize ecosystems. Third, their abundant connections to other species in an ecological network mostly reflect non-trophic or mutualistic interactions, including providing structural support for other species, significantly altering ecosystem properties to [dis]favor other species, altering metabolic rates of associated species, and modulating fluxes of energy and nutrient flow through the system.

Seagrasses are the main habitat for coastal marine ecosystems. They provide different services like sediment retention (and thus, clearer waters), coastal protection (in front of marine storms), shelter for marine organisms, etc. Therefore, the state of seagrasses is a convenient proxy for the state of coastal environment. In Malta, the results of RCP8.5 projections indicate a decrease of 20% of coverage area of Posidonia for the end-century. Although the projected reduction may seem moderate, it has to be kept in mind that the losses will be localized in the nearshore areas, so a large impact on water transparency is expected in beach areas. Ecosystem services will be probably be less affected (see **Figure 9.5**).

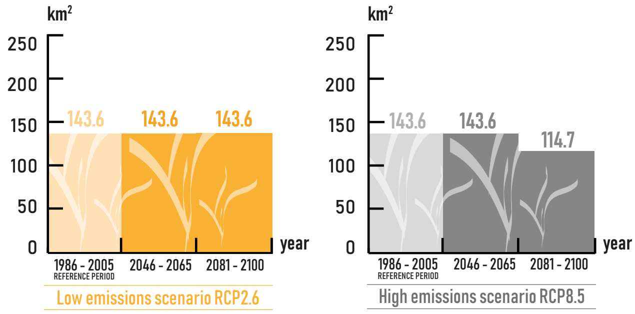


Figure 9.5. Seagrass evolution. Present coverage and projected changes (km^2) of the main species.

Source: SOCLIMPACT project deliverable [D4.4e Report] on estimated seagrass density.

9.3.1.2. Fire Weather Index (FWI)

The FWI system provides numerical non-dimensional ratings of relative fire potential for a generalized fuel type (mature pine stands) based solely on weather observations. FWI is part of the Canadian Forest Fire Danger Rating System established in Canada since 1971 (van Wagner, 1987). Furthermore, since 2007, FWI has been adopted at the EU level and used in a harmonized way throughout Europe by the European Forest Fire Information System (EFFIS) of the Copernicus Emergency Management Service (since 2015).

It is selected for exploring the mechanisms of fire danger change for the islands of interest, as it has been proved to adequately perform for several locations, including the Mediterranean basin. The index was calculated for the fire season (defined from May to October) over the Mediterranean for all models, scenarios and periods (see **Figure 9.6**).

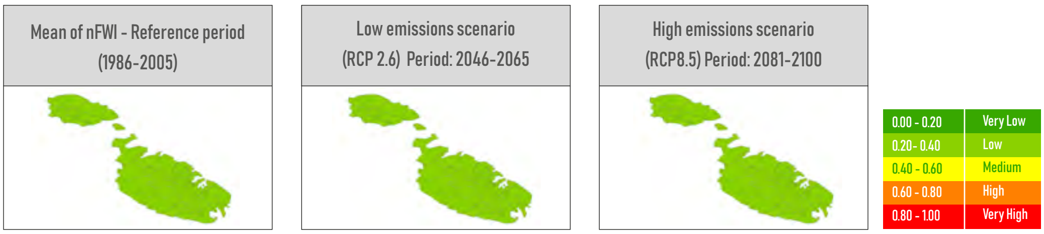


Figure 9.6. (Normalized) Fire Weather Index (EURO-CORDEX) with the color associated to the class of hazard.

Source: SOCLIMPACT project deliverable [D4.4c Report] on potential fire behaviour and exposure.

For Malta, N = 5 grid cells were retained from the model's domain. The ensemble mean and the uncertainty is presented for all periods and RPCs. As this island has small acreage, the grid cells present low land fraction and are influenced by the sea. It seems that under RCP2.6, the index slightly increases at the middle of the century, while it halts towards the end of the century. On the other hand, under RCP8.5, there is an increased fire danger of about 20% at the end of the century. It should be noted that the fire danger values for all points are classified as low, thus, for all scenarios/periods all areas belong to the same class, exhibiting also low uncertainty.

9.3.1.3. Beach flooding and related losses

One of the consequences of an increase in the mean sea level will be the flooding of coastal areas. This includes sand beaches, which are the main asset for tourism activities in most of the European islands. Therefore, estimating the potential risk of beach loss due to climate change is of paramount importance for the economy of those islands. Under mean conditions, we find that, at end of century, the total beach surface loss range from ~40% under scenario RCP2.6 to ~70% under scenario RCP8.5 (see **Figure 9.7**).

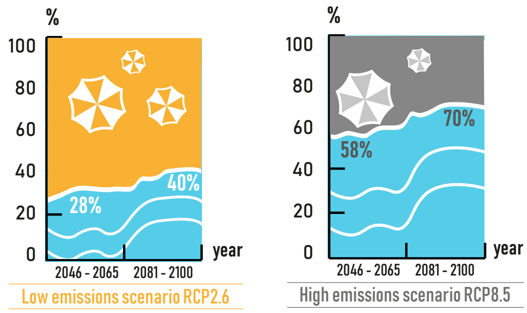


Figure 9.7. Beach reduction% (scaling approximation).
Source: SOCLIMPACT project deliverable D4.4d Report on the evolution of beaches.

9.3.1.4. Humidex

Humidex value is an equivalent temperature, which express the temperature perceived by people (the one that the human body would feel), given the actual air temperature and relative humidity.

The number of days with Humidex greater than 35 °C was selected as the more representative indicator for the assessment of inhabitants' and tourists' hazard on heat related climate change impacts. A day with Humidex above 35 °C describes conditions from discomfort to imminent danger for humans.

For Malta, N = 5 grid cells were retained from the models domain. In the following figure, the ensemble mean and the uncertainty are presented for all periods and RPCs. From 1.5 month in the present climate and above 2 months in the mid-century for both scenarios, Malta will have almost 4 months with discomfort conditions by the end of the century under RCP8.5 (see **Figure 9.8**).

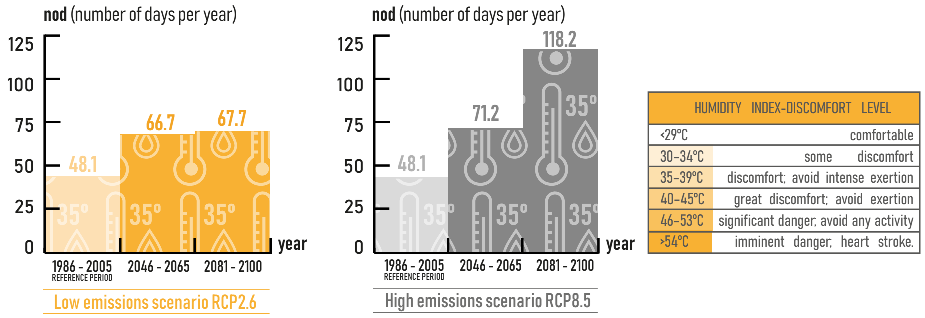


Figure 9.8. Number of days per year with Humidex > 35 °C (Euro-CORDEX).
Source: SOCLIMPACT project deliverable D4.3. Atlases of newly developed indexes and indicator.

9.3.1.5. Length of the window of opportunity for vector-borne diseases

Vector Suitability Index for Aedes Albopictus (Asian Tiger Mosquito)

Climate change can influence the transmission of vector-borne diseases (VBDs) through altering the habitat suitability of insect vectors. This is mainly controlled by increases of ambient air temperature and changes in the hydrological cycle. We explore if potential changes to meteorological conditions can affect the distribution of the Asian tiger mosquito (Aedes albopictus). Asian tiger mosquito is native to the tropical and subtropical areas of Southeast Asia; however, in the past few decades, this species has spread to many countries through the international transport of goods and increased travel

(Scholte and Schaffner, 2007). It is of great epidemiological importance since it can transmit viral pathogens and infectious agents that cause chikungunya, dengue fever, yellow fever and various encephalitides (Proestos *et al.,* 2015).

The multi-criteria decision support vector distribution model of Proestos *et al.* (2015) has been employed to estimate the regional habitat suitability maps. This is based on extending previous work on the environmental/climatic factors affecting the life cycle of the Asian tiger mosquito (Waldock *et al.,* 2013; Proestos *et al.*, 2015). The mosquito habitat suitability model combines seven meteorological indices based on field observations, extensive literature review and expert knowledge.

Malta is also a case where presence of the Asian tiger mosquito has been reported. In terms of climate projections for the future, Malta and Gonzo are a similar example to the Balearic Islands. Regional climate simulations suggest a transition from medium to low habitat suitability under a strong emission scenario (pathway RCP8.5). Milder changes and an average increase in the suitability is projected for simulations forced under pathway RCP2.6 (see **Figure 9.9**).

9.3.2. Aquaculture

The predicted impacts of climate change on the oceans and seas of the planet are expected to have direct repercussions on marine based aquaculture systems. Basic effects are the following (Soto and Brugere, 2008):

- Change in biophysical characteristics of coastal areas.
- Increased invasions from alien species.
- Increased spread of diseases.
- Changes in the physiology of the cultivated species by changing temperature, salinity, oxygen availability and other important physical water parameters.
- Changes in the differences between sea and air temperature which will alter the seasonality, frequency and severity of storms, cyclones and other extreme events, affect the stability of the coastal resources and potentially increase the damages in infrastructure.
- Sea level rise, acidification, changes in precipitation and other effects will also add to the changes in coastal ecosystems and environment, thus affecting production and infrastructure (= investments).

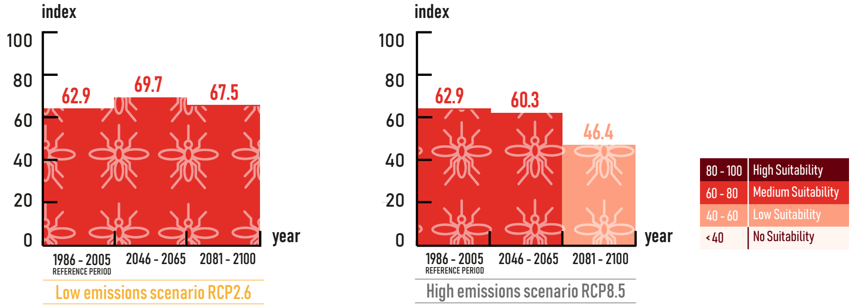


Figure 9.9. Habitat Suitability Index (HSI). [80-100: High Suitability; 60-80: Medium Suitability; 40-60: Low Suitability; <40 No Suitability].
Source: SOCLIMPACT project deliverable D4.3. Atlases of newly developed indexes and indicator.

It has been recognized that climate change impacts on aquaculture will be highly unpredictable and extremely localized. Examples of climate change hazards that can impact aquaculture are changes in ocean warming and acidification, as well as oceanographic changes in currents, waves, and wind speed. Sudden impacts such as an increase in the frequency and intensity of storms and heat waves are also impacting aquaculture. Other effects of climate change on aquaculture activities are increased invasions from alien species, increased spread of diseases and changes in the physiology of the cultivated species by changing temperature, oxygen availability and other important physical water parameters. An important indirect impact to aquaculture is the change in fisheries production due to climate change. Aquaculture of finfish is highly dependent on fisheries for feed ingredients. This is already a current problem with many fisheries overexploited and will only be intensified in the future.

Eventually, impacts caused by climate change can lead to loss of production and infrastructure. Climate change is also predicted to impact food safety, where temperature changes modify food safety risks associated with food production, storage, and distribution.

Socio-economic impacts on aquaculture are hard to assess due to the uncertainty of the changes in hazards and the limited knowledge these impacts have on the biophysical system of aquaculture species.

The following impacts were more closely studied:

- Changes in water temperature can directly affect the growth rate and Feed Conversion Ratio of the fish. Temperature also affects the oxygen levels and can cause harmful algae blooms, reduce water quality and an increase in occurrence of diseases and parasites which can than affect the fish or other culture species. A change in temperature can ultimately change the ranges of suitable species for a certain area but can also have positive impacts such as increased growth (mainly in tropical and sub-tropical regions) and a longer growing season. Primary productivity can also increase with increasing temperature, which may be beneficial for filter feeders such as mussels.

- Increased frequency and intensity of extreme weather events result in higher waves and storm surges and changes in salinity. These events result in loss of stock and damages to infrastructure and require adaptation in species selection, site selection and technologies.

9.3.2.1. Fish species thermal stress indicators

The objective of the current analysis is to identify and quantify the variations (future climate scenarios with respect to present climate) in the number and in the duration of events characterized by a Sea Surface Temperature (SST) exceeding a given threshold. The SST thresholds have been identified according to the farming and feeding necessities of several marine species, particularly relevant for the aquaculture sector in the Mediterranean Sea (MS).

Under scenario 8.5 at end of the century, the sea surface temperature could reach the thresholds adopted with important consequences, such as a change in the species distribution (see **Figure 9.10** and **Figure 9.11**).

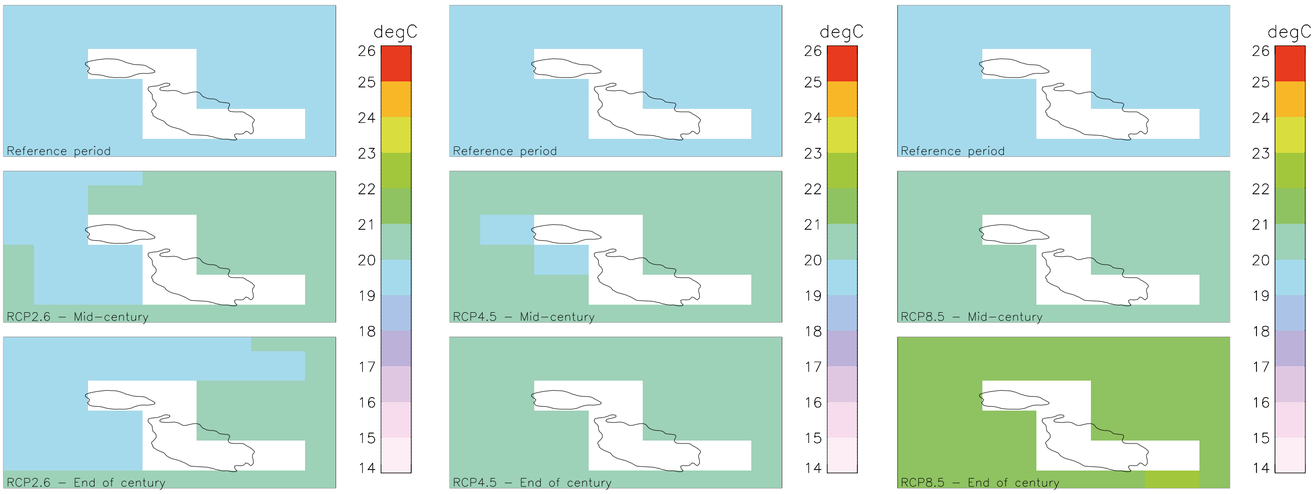


Figure 9.10. Non-normalized hazard from rising SST- From left to right: RCP2.6, RCP4.5, RCP8.5; from top to bottom: reference period, near future, far future.

Source: SOCLIMPACT Deliverable Report - D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

	Longest event (days) >20 degrees Mussels & clams	Longest event (days) >24 degrees Sea bream/Tuna	Longest event (days) >25 degrees Sea bass
Historic (1986-2005)	152 days	62 days	43 days
RCP 8.5 - mid century (2046-2065)	175 days	95 days	72 days
RCP 8.5 - end century (2081-2100)	201 days	123 days	98 days

Species	Thershold (°C)
European seabass, Dicentrarchus labrax	25
Gilthead seabream, Sparus aurata	24
Amberjack, Seriola dumerili	23
Atlantic Bluefin tuna, Thunnus thynnus	23
Japanese clam, Ruditapes decussatus	21
Blue mussel, Mytilus edulis	21
Manila clam, Rudtape philippinarum	20
Mediterranean mussel, Mytilus galloprovinciales	20

Figure 9.11. Number of days exceeding the threshold of sea surface temperature.

Source: SOCLIMPACT Deliverable Report - D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

9.3.2.2. Extreme Wave Return Time

Return times for a threshold of 7 m significant wave height (hs) were computed. This significant height has been identified by stakeholders as the critical limit for severe damages to assets at sea. Return times can be related to the payback times of investments and help assess potential economic losses and economic sustainability. In the future, under RCP8.5. (far future), the extreme wave return time will decrease depending on the model's outputs: for example, with the GUF model, the hazard class changes from high to low. Regarding the models of CNRM and LMD, there is not significant change (see **Figure 9.12**).

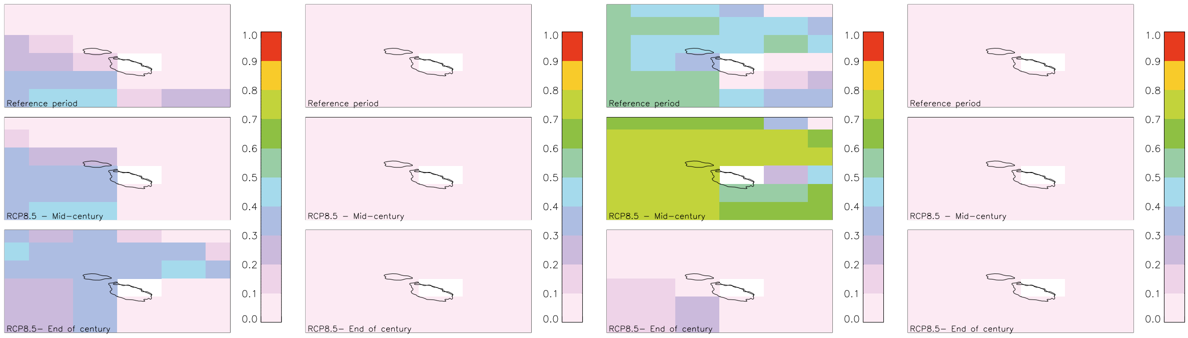


Figure 9.12. RCP8.5 - Normalized hazard from extreme waves - top left: CMCC; top right: CNRM; bottom left: GUF; bottom right: LMD.

Source: SOCLIMPACT Deliverable Report - D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

9.3.3. Energy

A series of indicators related to renewable energy productivity is presented. The productivity and variability of these renewable energy sources will depend on climate. The possibility of reduced productivity due to climate change poses a risk to the energy generation if it is based on these renewable energy sources, as well as a possible increase in the frequency and duration of solar and wind energy.

Standardized Precipitation Evaporation Index (SPEI)

The Standardized Precipitation Evapotranspiration Index (SPEI) is used as an indicator of water availability. In particular, this hazard index can serve as a representative indicator for increases in water demand for islands' residents, tourists and agriculture, while it also provides an indication on the available water stored in dams or underground resources.

In EURO-CORDEX, 12-km simulations Malta and Gonzo are represented by a very small number of grid points. Nevertheless, climate projections corroborate similar results with therest of the Mediterranean islands. There are strong indications towards moderate and extreme drier conditionsunderRCP8.5 and negative but near-normal SPEI values under RCP2.6. This will lead to additional increases in desalination and water pumping needs, a scenario which will substantially increase the cost for adaptation (see **Figure 9.13**).

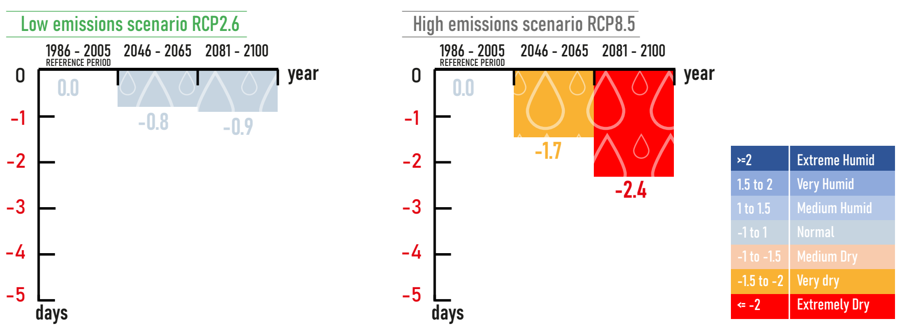


Figure 9.13. Ensemble mean, maximum and minimum values of the Standardized Precipitation Evaporation Index (SPEI) averaged over each SOCLIMPACT island and for each sub-period of analysis (EURO-CORDEX).

Source: SOCLIMPACT project deliverable D4.3. Atlases of newly developed indexes and indicator.

9.3.3.1. Percentage of days when T > 98th percentile - T98p

The T98p is defined as the percentage of time where the mean daily temperature T is above the 98th percentile of mean daily temperature calculated for the reference period 1986-2005. For RCP2.6, the indicator will reach 10% by the end of the century. On the other hand, the RCP8.5 future projections show that, daily temperatures will be above T98p for 26% on average (~94 days per year) of time (see **Figure 9.14**).

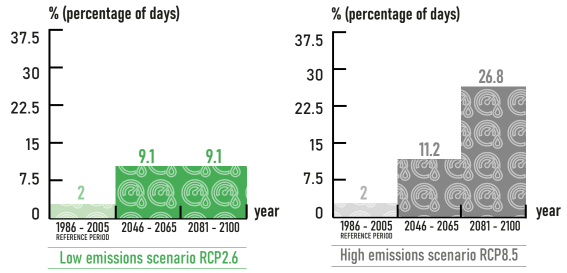


Figure 9.14. Percentage of days when T > 98th percentile (EURO-CORDEX).

Source: SOCLIMPACT project deliverable D4.3. Atlases of newly developed indexes and indicator.

9.3.3.2. Cooling Degree Days (CDD)

The Cooling Degree Days (CDD) index gives the number of degrees and the number of days that the outside air temperature at a specific location is higher than a specified base temperature, providing the severity of the heat in a specific time period, taking into consideration outdoor temperature and average room.

For RCP2.6, we found that, for near future and far future, the increase is about 50%. On the other hand, the analysis of the RCP8.5 provides a more devastating picture, as the number of CDD will be around four times larger than the reference period (see **Figure 9.15**).

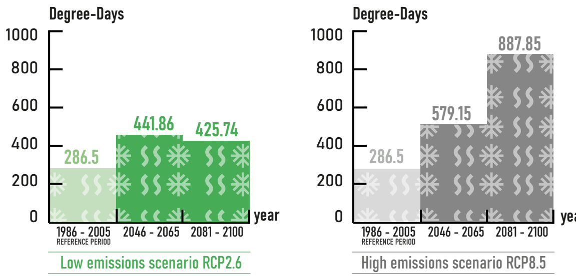


Figure 9.15. Cooling Degree Days. Ensemble mean of EURO-CORDEX simulations, relative change (%).

Source: SOCLIMPACT project deliverable D4.3. Atlases of newly developed hazard indexes and indicators with Appendices.

9.3.4. Maritime Transport

9.3.4.1. Sea Level Rise (SLR)

Sea Level Rise (SLR) is one of the major threats linked to climate change. It would induce permanent flooding of coastal areas with a profound impact on society, economy and environment. Moreover, an increase in the mean sea level would result in a larger impact of coastal storms with the consequent increase of risk. The results are presented in terms of mean sea level rise. For Malta, the SLR ranges from 24.10 cm (RCP2.6) to 64.99 cm (RCP8.5) at the end of the century (see **Figure 9.16**).

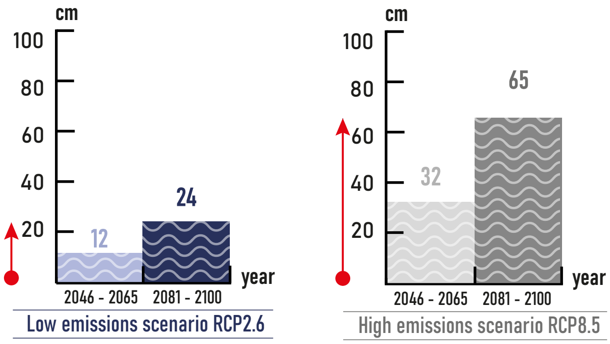


Figure 9.16. Mean sea level rise (in cm) with respect to the reference period (1986-2005). Own elaboration based on global and regional simulations.

Source: SOCLIMPACT project deliverable 4.4b Report on storm surge levels.

9.3.4.2. Storm surge extremes

Storm surge events, characterized by positive extreme sea levels and mechanically forced by atmospheric pressure and wind, are the main responsible for coastal flooding, especially when combined with high tides. To date, the only ensemble populated with enough number of members to compute meaningful statistics on climate projections is the one produced for the Mediterranean by Lionello *et al.* (2017). This ensemble consists on 6 simulations run with the HYPSE model at 1/4° of spatial resolution and forced by the high-resolution wind fields from the MedCORDEX ensemble, which in turn is nested into CMIP5 global simulations.

The simulations are run for the period 1950-2100, thus covering the historical period as well as the whole 21st century. Complementary, the ensemble includes three hindcast simulations that are used to establish present reference levels. Storm surge could decrease an amount of 20% under RCP8.5 (far future). Nevertheless, it is worth noting that the mean sea level rise is expected to be critically larger in this same period and scenario (see **Figure 9.17**).

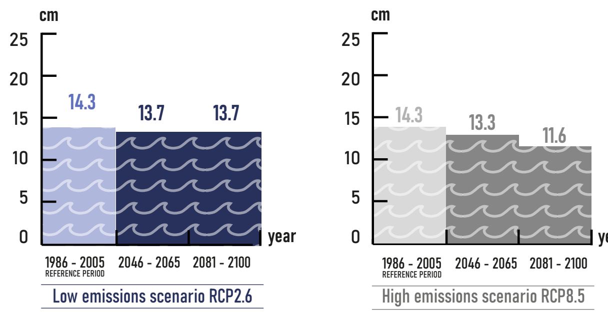


Figure 9.17. 99th percentile of atmospherically forced sea level (in cm) averaged for the hindcast period, the near future (2046-2065) and the far future (2081-2100) under scenarios RCP2.6 (with scaling approximation) and RCP8.5, relative change in brackets.

Source: SOCLIMPACT project deliverable 4.4b Report on storm surge levels.

9.3.4.3. Wind extremes

The wind extremity index NWIX98 is defined as the number of days per year exceeding the 98th percentile of mean daily wind speed. This number decreases in the far future with a strongest value under RCP8.5 (- 22.9%). Like the NWIX98, the 98th percentile of daily wind speed, WIX98, decreases but with a more significant magnitude for RCP8.5 (see **Figure 9.18**).

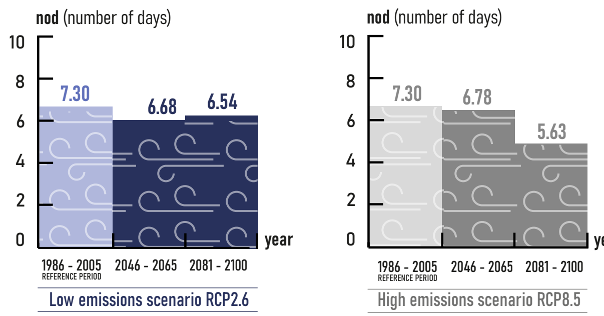


Figure 9.18. Wind Extremity Index (NWIX98). Ensemble mean of EURO-CORDEX simulations.

Source: SOCLIMPACT project deliverable D4.3. Atlases of newly developed indexes and indicator.

9.3.4.4. Wave extremes (99th percentile of significant wave height averaged)

Marine storms can have a negative impact on maritime transport, coastal-based tourism and aquaculture, among other activities. To illustrate this impact, the 99th percentile of significant wave height averaged has been chosen. A decrease in the extreme wave height is found being larger under scenario RCP8.5 as illustrated in the following maps (see **Figure 9.19**).

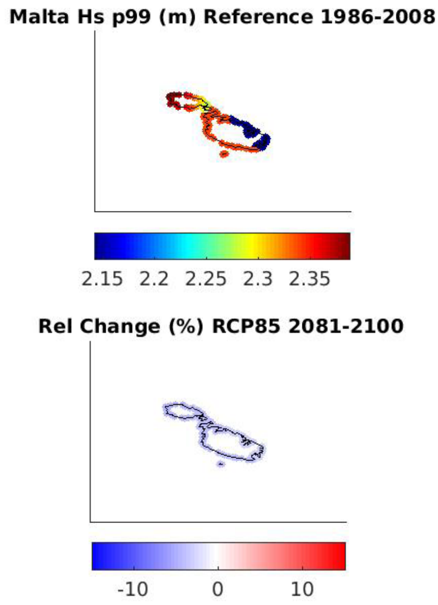


Figure 9.19. The 99th percentile of significant wave height averaged for the reference period and the relative change for the RCP8.5. Own elaboration based on global and regional simulations.

Source: SOCLIMPACT project deliverable 4.4b Report on storm surge levels.

9.4. Risk Assessment

9.4.1. Tourism

9.4.1.1. Loss of attractiveness due to increased danger of forest fires in touristic areas

For the reference period (1986-2005), the overall risk of forest fires is very low for Malta (the lowest among all islands). The future risk will change from very low to low under RCP8.5 at the end of century. Only Malta has the three components balanced. Considering the exposure component, only the level of exposure is represented in the calculation of the final risk scores. Considering the vulnerability component, only the adaptive capacity is represented; indeed, the flammability index as indicator of the sub-component of sensitivity is almost 0. The indicators of numbers of firefighters (volunteers) and the occupation rate (%) are the most representative within the adaptive capacity sub-component (see **Figure 9.20** and **Figure 9.21**).

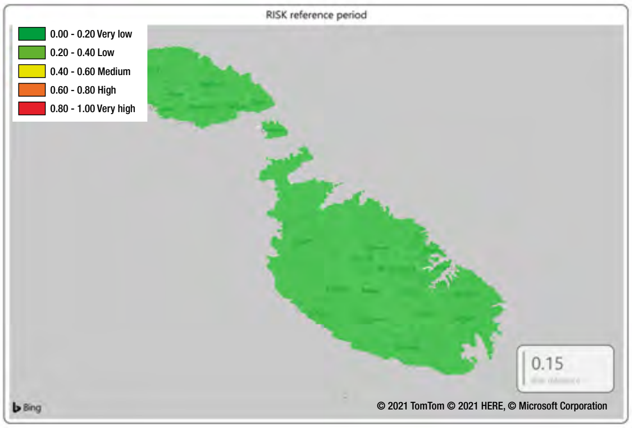


Figure 9.20. Risk score for the reference period.

Source: SOCLIMPACT Deliverable [Report – D4.5](). Comprehensive approach for policy makers.

9.4.1.2. Loss of attractiveness due to marine habitats degradation

The island shows starting surrounding conditions favourable to face the risk of seawater heating. Although the island scores the second worst in adaptive capacities to cope with the main vectors of the problem, there are two particular aspects that compensate that disadvantage. Firstly, the island does not hold attributes to attract classical massive tourism to its coasts, such as large beaches and exuberant marine ecosystems. Conversely, Maltese tourism is attracted by its cultural attributes and business. Secondly, its marine tourism industry heavily rests on activities that are not sensitive to the quality of the marine environment, as the motorised ones. Because of it, even if Malta shares with Sicily the lowest risk related to seawater heating, this island shows lesser uncertainties than those showed by the Italian island.

The mentioned advantages and disadvantages of Malta are depicted in the next figures. The further the criteria or sub-criteria is located from the centre of the graph, the more it affects the risk (see **Figure 9.22** and **Figure 9.23**).

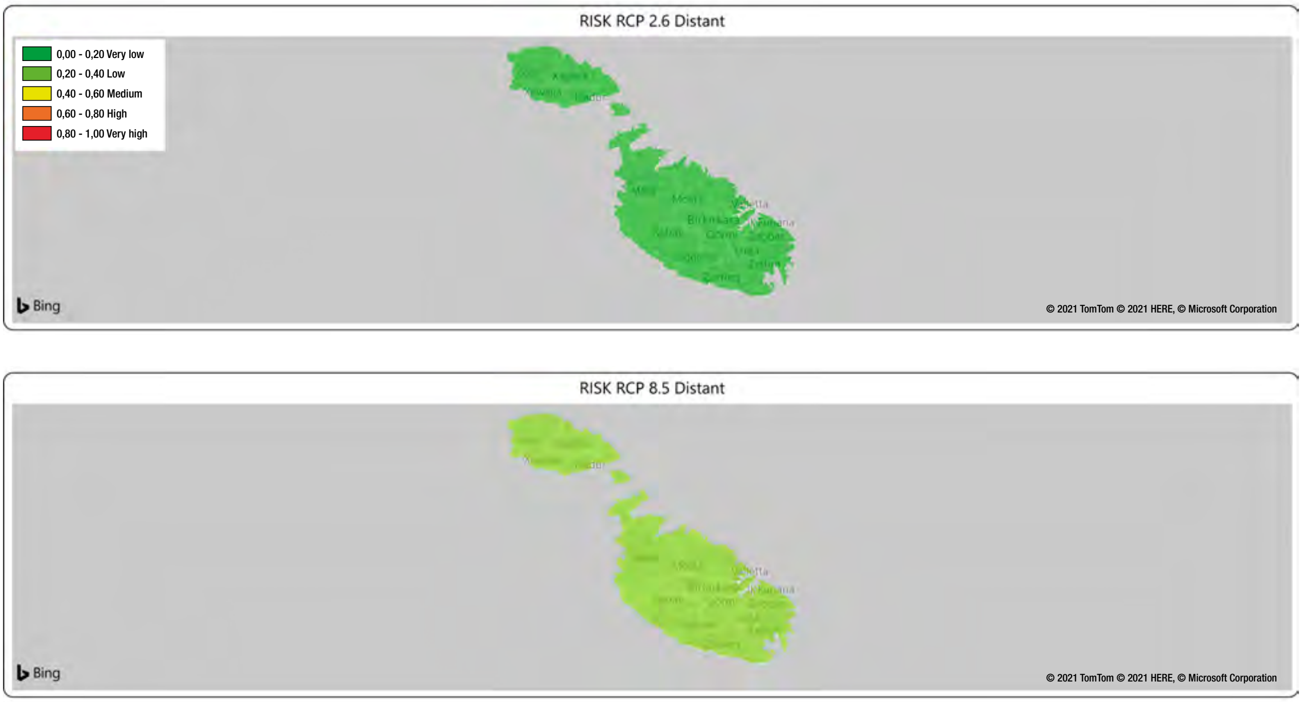


Figure 9.21. Risk score at the end in the distant future (2081-2100) under RCP2.6 (Ambitious Mitigation Policies) and RCP8.5 (business as usual).

Source: SOCLIMPACT Deliverable [Report - D4.5.]() Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

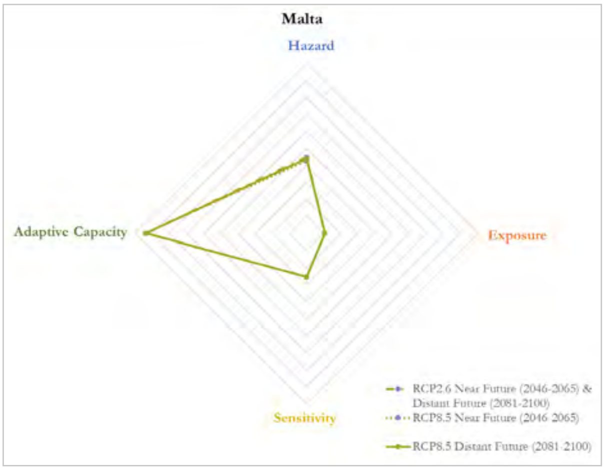


Figure 9.22. Global weights of each criteria and sub-criteria in the final score.

Source: SOCLIMPACT Deliverable [Report – D4.5](). Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

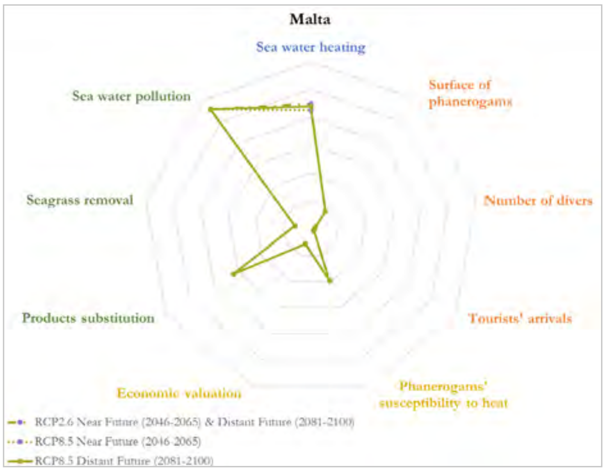


Figure 9.23. Global weights of each criteria and sub-criteria in the final score.

Source: SOCLIMPACT Deliverable [Report – D4.5](). Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

9.4.1.3. Loss of competitiveness of destinations due to a decrease in thermal comfort

The island shows some disadvantage in the criterion Sensitivity, contributing 52.3% to the final score. In particular, it is due to the heat-sensitive activities that tourists carry out when visiting the destination, given that Maltese tourism is attracted by its cultural attributes. On the other hand, Malta scores average in the Hazard, in Exposure and in Adaptive Capacity, being especially favourable the medical attention in the latter case. The mentioned advantages and disadvantages of Malta are depicted in the next figure. The further the criteria or sub-criteria is located from the centre of the graph, the more it affects the risk (see **Figure 9.24** and **Figure 9.25**).

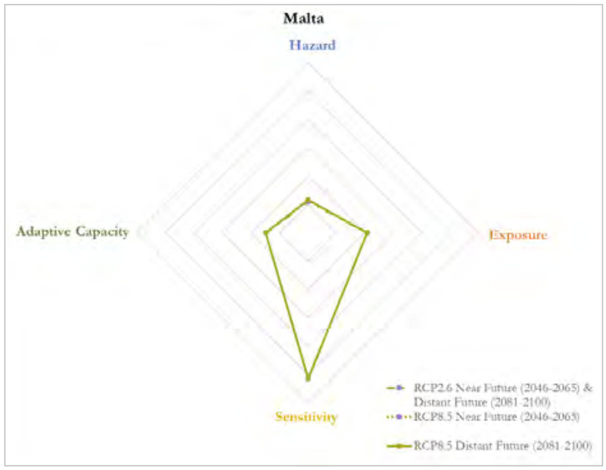


Figure 9.24. Global weights of each criteria and sub-criteria in the final score.

Source: SOCLIMPACT Deliverable [Report – D4.5](). Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

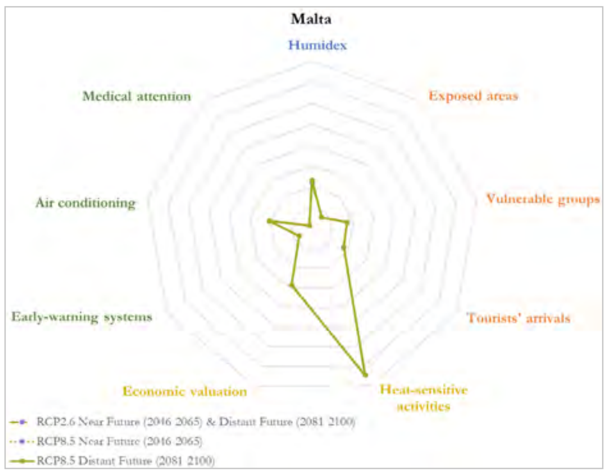


Figure 9.25. Global weights of each criteria and sub-criteria in the final score.

Source: SOCLIMPACT Deliverable [Report – D4.5](). Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

9.4.1.4. Risk of increased fragility of aquaculture activity due to extreme weather events

Results for the hazard induced by mean wave motion appear to classify most Mediterranean offshore farm locations as semi-exposed sites (unlike those in the Atlantic, which are offshore). The probability of occurrence of extreme events that might prove unendurable for infrastructures moderately lowers the cumulative hazard, except for Malta, which is, however, affectd by higher uncertainty under all scenarios, as inferred from the difference between the best and worst cases. Malta appears to be the most exposed among the islands studied in the Meditarrean, due to the local size of the sector both in absolute and relative terms (see **Table 9.3**).

Table 9.3. Risk results for impact chain "Extreme Weather Events" for the Mediterranean islands.

Risk	Best-case scenario					Worst-case scenario				
	Reference period	Mid century		End century		Reference period	Mid century		End century	
	Hist.	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	Hist.	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Corsica	0.19	0.19	0.19	0.20	0.21	0.25	0.25	0.26	0.28	0.26
Cyprus	0.23	0.23	0.23	0.23	0.22	0.23	0.23	0.23	0.23	0.22
Malta	0.26	0.26	0.26	0.26	0.26	0.42	0.45	0.56	0.45	0.36
Sardinia	0.30	0.32	0.32	0.28	0.31	0.33	0.33	0.34	0.33	0.33
Sicily	0.20	0.20	0.20	0.20	0.20	0.30	0.34	0.33	0.33	0.26

9.4.2. Energy

According to the risk analysis, it is expected a large cooling energy demand increase. Besides, desalination demand, which is already high, should also increase for both emissions scenarios, but much more under RCP8.5.

Malta is an island with large constraints on land-based RES, due to its small size and large population density. Additionally, present onshore wind energy resources are limited. PV energy potential is good, and the energy droughts indicator shows a high stability. PV energy can be integrated in buildings and has, therefore, a higher potential, though its installation in apartment blocks faces uncertainties like the possibility of redevelopment of existing buildings based on an increase in the number of storeys. As a consequence, the NECP (2019) only projects a very limited increase of RES share from a present value of 9% to 11.5% in 2030. Such a low share moves Malta away from the EU targets. Offshore PV might be the main renewable energy technology with substantial potential, particularly if the capacity of the interconnector with Sicily could be increased or battery storage could be installed in sufficient quantities for grid stability reasons. In this respect, one of the first tests in the world with offshore PV was performed in Malta (Grech *et al.*, 2016).

The scores for the expected change of renewable energy productivity point to a small decrease, except under RCP8.5 by end of the century, when a relatively large decrease is projected, particularly for wind energy. The stability characteristics would show limited changes under RCP2.6, and would worsen clearly under RCP8.5 for wind energy.

The risk associated to cooling energy demand shows presently a medium value, which would remain almost constant under RCP2.6 and would nearly reach a high value under RCP8.5 by the end of the century. The projected increase of the risk score is relatively small despite the large increase in CDD under RCP8.5 (CDD score increases twofold by mid of century and threefold by end of century), due to the low weight assigned to the hazard. In this case, the availability of observed cooling energy demand data was very low (only 4 years), which is insufficient for calculating meaningful weights through correlation with the different indicators.

A medium score is also obtained for the risk linked to desalination energy demand for present climate conditions. The projected increase of the risk is higher than for cooling energy demand, reaching high scores under RCP8.5. In this case, the weights offer a very interesting information about the impact of adaptation options. In this case, we have a rather long desalination energy demand series (2004-2018). If we take the whole series, there is a strong decreasing trend in demand until 2009. If we take the whole time-series for the correlations, these show counterintuitive values, while if we take the series from 2009-2018, the correlation is -40%, which is a result that lies within the expectations (drier conditions are associated to more desalination). Another example of this unexpected behaviour is the correlation between desalination demand and population or number of tourists: it is negative if the whole series (2004-2018) is used (implying less desalination demand for higher population or number of tourists), but it is strongly positive if the period 2009-2018 is taken.

A report from the Water Services Corporation of Malta (2018) offers a very likely reason for this behaviour: there was a strong reduction in water leakages from 2004 to 2009, while water losses have not varied much between 2009 and 2018. Therefore, the strong reduction in desalination energy demand from 2004 to 2009 is clearly driven by the infrastructure improvement, overriding the impact of the factors included quantitatively in the impact chain calculations. The reduction of water leakages is a demand side management option, and its impact over the short term shows the potential importance of these kind of measures.

We have opted, therefore, to calculate all correlations and weights using the desalination demand series from 2009-2018. As a result, the climate hazard receives a weight of 0.2, while the exposure and vulnerability components have a weight of 0.38 and 0.42, respectively. Most individual indicators for the exposure and vulnerability components show a high correlation with the observed desalination demand. It is noticeable that tourism seasonality has been decreasing through the selected period, and shows a large, but negative, correlation with desalination demand (see **Table 9.4**).

Table 9.4. Final risk scores for Malta: cooling and desalination energy demand, for the historical and future periods.

Risk scores	Hist. reference	RCP2.6 (2046-2065)	RCP2.6 (2081-2100)	RCP8.5 (2046-2065)	RCP8.5 (2081-2100)
Cooling	0.49	0.51	0.51	0.53	0.57
Desalination	0.47	0.54	0.55	0.61	0.67

Categorization:

0.00 – 0.20 Very low	0.20 – 0.40 Low	0.40 – 0.60 Medium	0.60 – 0.80 High	0.80 – 1.00 Very high

Source: SOCLIMPACT project Deliverable 4.5. Comprehensive approach for policy makers.

* Energy demand

- Certain data illustrate the strong impact that demand-side management options can have on energy demand. In the case of Malta, water losses in the distribution network were tackled through a leak management strategy during several years in such a way that the water losses were nearly halved from 2004 to 2009. This factor has been decisive in the evolution of the desalination energy demand, which has decreased 20% from 2004 to 2018, at the same time that GDP has grown 80%, the number of tourists has doubled and drought conditions have worsened.
- A clear demand management option for reducing cooling demand is the improvement of the energy efficiency of buildings. The energy efficiency directive of the EU sets binding targets for all European countries, but the data about the efficiency classes of buildings are rather limited and difficult to access. The scarce data available indicate that there is much room for improvement in this respect. A consequent implementation of energy efficiency measures in buildings could reduce clearly the effect of increasing temperatures on energy demand.
- Digitalisation is key in EU strategies. In this respect, demand side management options for adaptation to generation peaks and troughs should be developed as much as possible through digitalisation, prioritising automatic instead of manual adaptation.

* Energy supply

- The frame for energy supply in the islands are the binding targets established in the 2030 climate and energy EU framework and the long term horizon of a decarbonized energy system by 2050.
- The combination of different types of offshore renewable energy sources in the same platform is also attracting interest, as the different sources can exhibit complementarity in time and the combined output can thus be more stable and reliable. The different RES can also share part of the installations, like the connection to land, reducing their cost (Pisacane *et al.*, 2018; MarineEnergy, 2019a). The European Union is trying to promote such combinations, through projects like MUSICA (Multiple Use of Space for Island Clean Autonomy) which will design and test a floating offshore platform integrating wind, PV and wave energy for use on islands (MarineEnergy, 2019b), and plans to develop roadmaps for its deployment in three case study islands, among them Malta and the Canaries (MaREI, 2020).
- New financing possibilities linked to the recently approved EU COVID-19 recovery fund, and over a longer term associated to the European Green Deal, should facilitate the deployment of renewables in the islands, as the energy transition is a key target.
- Interconnections to mainland are very important for supply safety. Excessive dependency on interconnections to mainland should be nevertheless avoided, due to risk of blackouts, as the failure of a single element (one transmission line) can knock out instantaneously a large proportion of the power of an island and even cause an island-wide blackout, as has occurred several times in Malta in the last years.

Read more*: Hazard indicator computation and normalization on Appendices.*

9.4.3. Maritime Transport

The Impact Chain operationalization for Malta highpoints a higher present relative risk for isolation due to maritime transport disruption compared to Cyprus and Crete (risk value of 0.376). This is mostly related to the high values of nature and level of exposure indicators due to the combination of small number of ports and high value of goods. Two other contributors to the relatively higher risk value, related to increased vulnerability, is the small number of harbour alternatives (e.g., airports) and the small percentage of renewables in the total energy mix. For RCP2.6, the risk is expected to slightly decrease, mainly due to an expected increase of the renewable energy contribution, although Malta will be still classified as a low risk region. On the contrary, under the RCP8.5 pathway, the risk for transport disruption in the Maltese islands is projected to increase and marginally classified as low for the middle of the 21st century (risk value of 0.395). For the end of the current century the risk is projected to increase into medium values (0.414). This is due to the lower contribution of renewables in this high-emission scenario and the increase of the hazard indicators (mainly extreme winds and mean sea level rise). The mean sea level in particular is expected to rise by 65 cm posing an additional threat to harbour infrastructure. READ MORE about the risk indicator computation: normalization of sub-component indicators on Appendices (see **Table 9.5**).

Table 9.5. Summary of present and future risk of isolation due to maritime transport disruption for each island and scenario based on the Impact Chain operationalization.

Risk value per island	Historical reference	RCP2.6 MID	RCP2.6 END	RCP8.5 MID	RCP8.5 END
Cyprus	0.241	0.210	0.218	0.258	0.292
Crete	0.229	0.208	0.201	0.257	0.282
Malta	0.376	0.347	0.335	0.395	0.414
Corsica	0.220	0.194	0.194	0.243	0.273
Canary Islands	0.336	0.292	0.250	0.346	0.341
Balearic Islands	0.326	0.281	0.264	0.331	0.344

Categorization:

0.00 – 0.20 Very low	0.20 – 0.40 Low	0.40 – 0.60 Medium	0.60 – 0.80 High	0.80 – 1.00 Very high

Source: SOCLIMPACT Deliverable Report – D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

9.5. Impacts on the Blue Economy Sectors

9.5.1. Tourism (Non-Market Analysis)

In order to analyze the reactions of tourists to the impacts of climate change and the preferences for adaptation policies, several hypothetical situations were posed to 255 tourists visiting Malta, whereby possible climate change impacts were outlined for the island (e.g., beach erosion, infectious diseases, forest fires, marine biodiversity loss, heat waves, etc.) (see **Figure 9.26**).

Firstly, tourists had to indicate whether they would keep their plans to stay on the island or find an alternate destination if the impact had occurred, which allows predictions of the effects on tourism arrivals to be made for each island. Secondly, tourists were asked to choose between various policy measures funded through an additional payment per day of stay – the tourists' choices being an expression of their preferences for attributes/policies. To estimate the results, the conditional logit model was run by using the Stata software.

In general, data confirms that tourists are highly averse to risks of infectious diseases becoming more widespread (75.30% of tourists would change destination). Moreover, they are not willing to visit islands where water is scarce for leisure activities (67.20%) or where marine wildlife has disappeared to a large extent (62.10%). On the other hand, policies related to the prevention of infectious diseases (9.2 €/day), water supply reinforcement (8.2 €/day), and marine habitats protection (5.7 €/day) are the most valued, on average, by tourists visiting this island.

Although climate change impacts are outside the control of tourism practitioners and policy makers, they can nevertheless utilise this knowledge to improve the predictability of the effect that certain adaptation policies and risk management strategies, and develop their plans accordingly (see **Figure 9.27**).

The impact of increased temperatures and heat waves on hotels' prices and revenues

In order to assess how the variation in temperature impacts on the tourism sector through changes in tourism demand, our research question was: "How do increasing tempera-

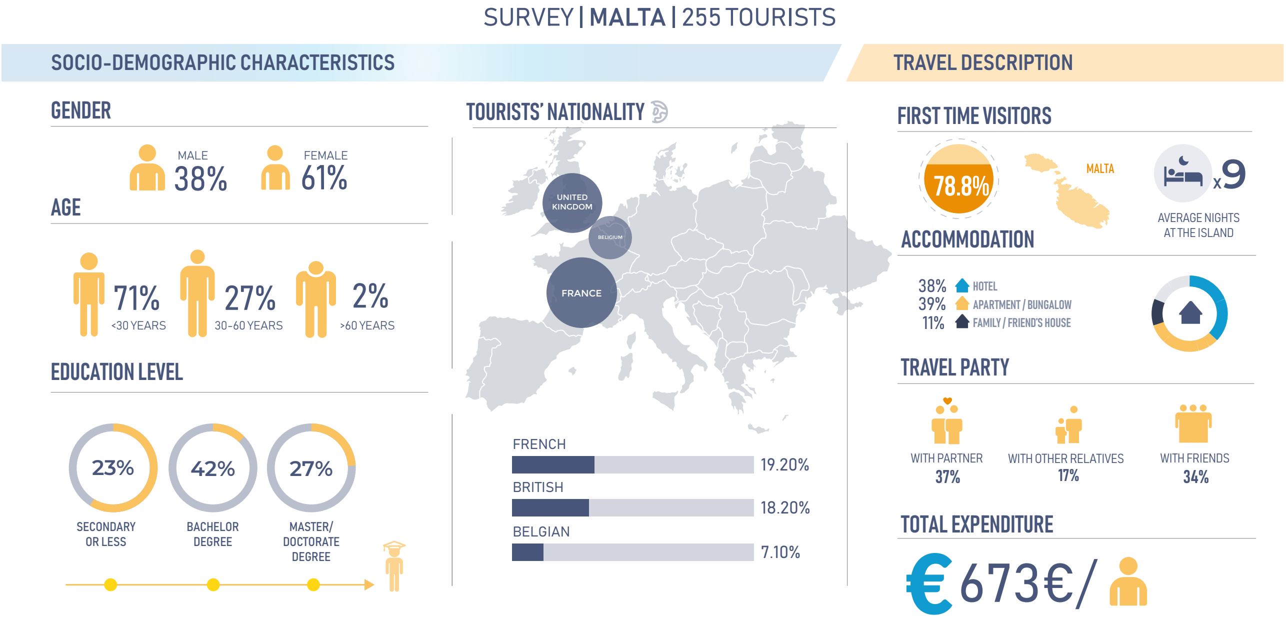


Figure 9.26. Socio-economic characteristics and travel description: tourists visiting Malta.
Source: SOCLIMPACT Deliverable Report D5.5. Market and non-market analysis

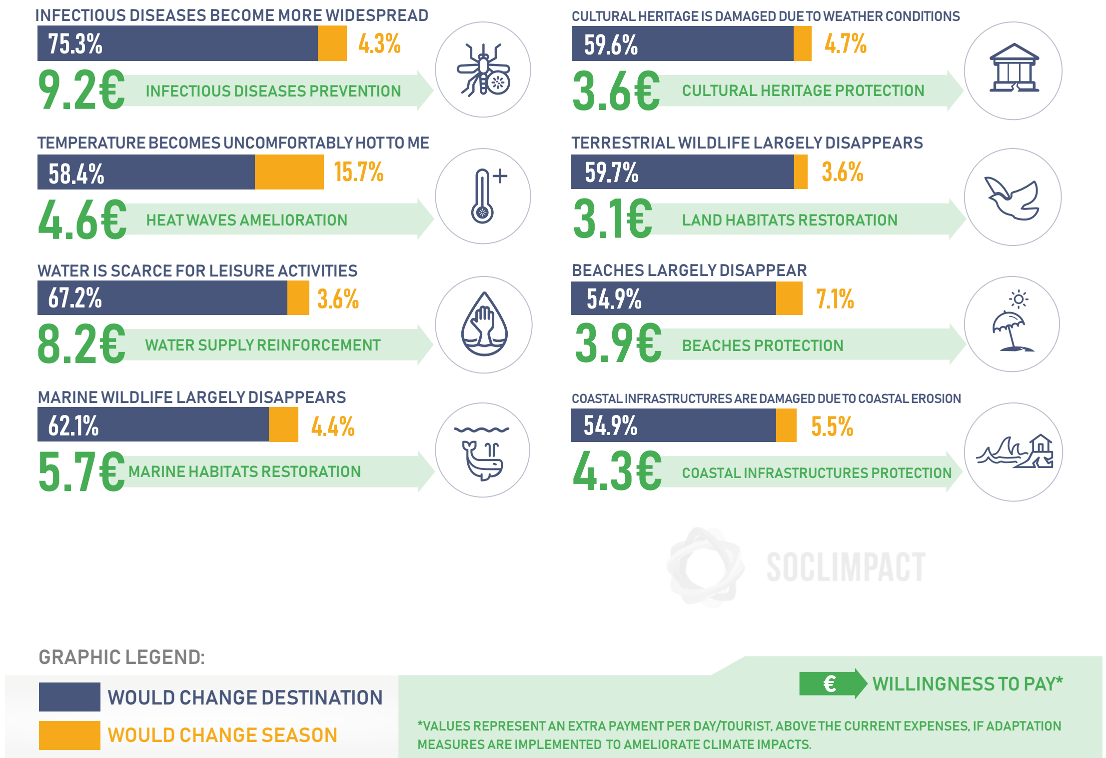


Figure 9.27. Tourists' response to climate change impacts and related policies: tourists visiting Malta.
Source: SOCLIMPACT Deliverable Report D5.5. Market and non-market analysis.

tures (and heat waves) impact prices and, more in general, expenditure of tourists?" Arguably, when temperatures grow, tourists adjust their behaviour: they might switch destination, or they might stay longer or shorter depending on their attitudes and preferences. In turn, all these changes modify the market equilibrium, pushing tourism companies to adjust their prices to re-establish the equilibrium between demand and supply. The change in demand and the change in price determine the change in tourism expenditure which is, from the destination's perspective, tourism revenue.

We monitored current weather conditions posted on several weather forecast providers and daily prices posted on Booking.com by hotels. We then estimated the link between daily temperature and daily price, controlling for all the other factors affecting prices. We finally applied these estimates to the increase in the number of days with excessive temperature projected for the future in two scenarios (RCP2.6 and RCP8.5) and in two time horizons (near future, about 2050, and distant future, about 2100).

Among the different indicators linked to thermal stress, we focus on two: the number of days in which the temperature is above the 98th percentile and the number of days in which the perceived temperature is above 35 °C. Although the impact for both indices was computed, in this document we only report the second one (named Humidex) because it is the most intuitive and because human thermal stress is more related to the absolute value of the temperature than its deviation from some pre-determined distribution. We assumed that thermal stress appears when the perceived temperature grows above 35 °C.

As thermal stress is delimited in the summer months, and this is when the great majority of tourists arrive in these islands, the whole analysis has been carried out in six months only: from May to October included. In other words, we assume that there is no thermal stress (and hence, no impact on tourism) in the rest of the year.

Initially, three islands were investigated: Corsica, Sardinia, and Sicily, given the massive amount of potential data. Other estimations were provided for Malta using the Index of Distance in Destination Image to position each island in a range that goes from Sardinia / Corsica on one side and Sicily on the other side. Without entering the details of the extrapolation method a summary of results is reported here (see **Table 9.6**):

Table 9.6. Estimation of increase in average price and revenues for Malta.

Actual share of days in which Humidex > 35 degrees	Future scenario considered	Days in the corresponding scenario in which Humidex > 35 degrees	Increase in the average price	Increase in the tourism overnight stays	Increase in tourism revenues
26.36%	RCP 2.6 near	36.55%	1.5%	0.3%	1.8%
	RCP 2.6 far	37.10%	1.5%	0.3%	1.9%
	RCP 8.5 near	39.01%	1.8%	0.4%	2.2%
	RCP 8.5 far	64.77%	5.5%	1.1%	6.7%

Source: SOCLIMPACT Deliverable Report - D5.3. Data Mining from Big Data Analysis.

According to these findings, the average increase in temperature, which is correlated to a growing thermal stress for tourists, brings an economic advantage to tourism destinations. This is only an apparent contradiction with previous findings. This study does not neglect the fact that if islands are too hot, tourists will choose to move to other (cooler) destinations, that theoretically exist. Then, the increase in tourism (and tourism revenues) stem from the fact that, when the temperature is too hot, people would prefer to move to coastal areas (where the climatic conditions are more bearable) than staying inland or in cities. Future trends will also facilitate this pressure of tourism demand (think about the spreading of smart working activities where, in principle, the worker can relocate wherever he/she wants).

9.5.2. Aquaculture

The effects of increased sea surface temperatures on aquaculture production were calculated using a lethal temperature threshold by species and considering the production share of the region. Four different future scenarios shown by IPCC estimations (RCP2.6 and RCP8.5 near and distant) were analysed, which correspond to four water temperature increases in the region (mean values), with respect to the reference period.

To do this, we assume two main species cultured in this region: Seabream (SB) and Tuna (T), and a model of production function, calculating the monthly biomass production which depends on the monthly water temperature. Results are presented on a yearly basis (mean values). In order to facilitate the interpretation of the results, we present the value of production of the last year available, for which we calculate the new values under the different climate change scenarios.

As expected, the production levels (tons) will decrease for both, low and high emissions scenarios. In both cases, the average annual temperatures are projected in levels below 23 °C and 24 °C, which are the thresholds of thermal stress for Bluefin tuna and Seabream species (see **Figure 9.28**).

19,291.00 *	16,918 .21 ▼(-12.3%)	17,285.74 ▼(-10.4%)
19.3	20.1	20.0

PRODUCTION SHARE	%
SEABREAM	10
BLUEFIN TUNA	90

19,291.00 *	14,834.78 ▼(-23.1%)	7.465,62 ▼(-61.3%)
19.3	20.6	21.8

Figure 9.28. Estimations of changes in aquaculture production (tons), due to increased sea surface temperature.

Source: SOCLIMPACT Deliverable Report D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

9.5.3. Energy

Climate change may impose welfare reductions to the European islands' societies by affecting thermal comfort. Cooling Degree Days (CDD) are a measure of how much (in degrees), and for how long (in days), outdoor air temperature is higher than 21 °C. The CDD is used as a measure of the energy needed to cool buildings. The increase in CDD and the energy demand (GWh/year) for cooling are estimated for the islands, under different scenarios of global climate change. Under the high emissions scenario, it is expected that the CDD increase to 887 CDD[2]. Under this situation, the increase in cooling energy demand is expected to be 240 % (see **Figure 9.29**).

The Standardized Precipitation Evapotranspiration Index (SPEI) is analysed as a representative indicator for increases in water demand for islands' residents, tourists and agriculture, while it also provides an indication on the available water stored in dams or underground resources. To estimate the increase of energy demand due to the increase in water demand, it was assumed that most of the islands will have to produce desalinated seawater (or groundwater) to meet further increases of demand. Thus, the estimation of the increase in energy demand (GWh/year) to produce more drinking water has been done based on the energy consumption required to desalinate seawater.

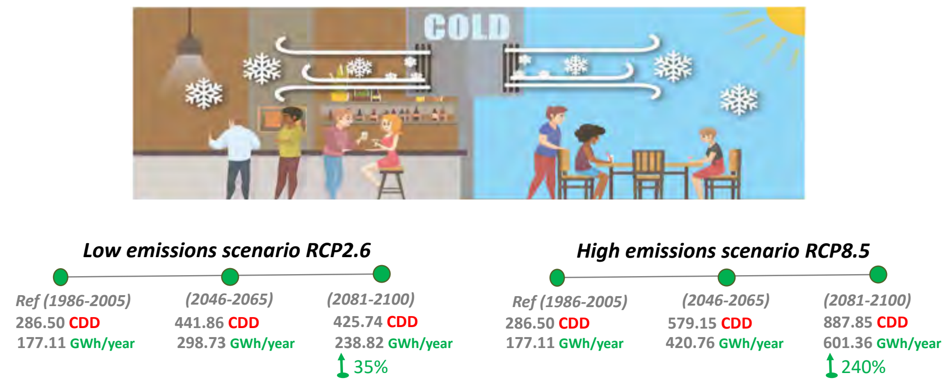


Figure 9.29. Estimations of increased energy demand for cooling in Malta under different scenarios of climate change until 2100.

Source: SOCLIMPACT Deliverable Report D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

[2] The indicator is computed by multiplying the number of days exceeding the threshold by the difference in temperatures.

Under the low emissions scenario (RCP2.6), there are not significant changes in the SPEI indicator, that will remain in its ¨normal¨ level, as it is nowadays. Nevertheless, an increase of 36 % in desalination energy demand is expected. Under RCP8.2, the scenario alerts on a severe aridity leading to an increase of 159% of the energy demand (see **Figure 9.30**).

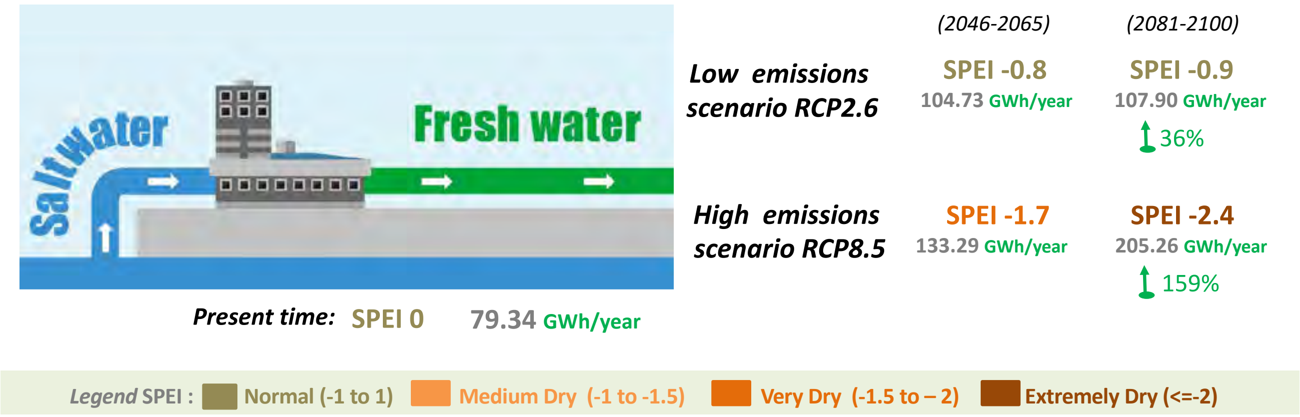


Figure 9.30. Estimations of increased energy demand for desalination in Malta under different scenarios of climate change until 2100.

Source: SOCLIMPACT Deliverable Report D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

9.5.4. Maritime Transport

For maritime transport, the impact of Sea Level Rise (SLR) on ports' operability costs of the island were calculated with reference to 1 meter; which is defined as the investment needed to increase the infrastructures' height by 1 meter. There is not necessarily a strict correspondence between the SLR and the required elevation of port infrastructures, as it also depends on the coastal hydrodynamic and the shape of dikes of each port. By experts' recommendation, it was assumed that 1 meter increase in port height is required to cope with the SLR under RCP8.5 scenario of emissions. Extrapolation for other RCP scenarios was then conducted based on proportionality.

The starting point was the identification of the principal ports in each island (economic relevance). Second, the analysis of the different port areas (exterior, ramps, oil, etc.), and their uses. Third, the elevation costs were estimated per each area and port separately (considering 1 meter elevation). Thus, the costs of 1 meter elevation presented are the sum of all areas and ports analysed, and including the rest of the ports of the island (if applicable) based on proportionality. Estimations consider that all ports areas of the entire area should be elevated at the same time. In other words, the economic values can be interpreted as the depreciation (amortization) costs of the investment needed to increase all porsts' infrastructures' in the island for 125 years time horizon. No discount rate has been applied.

As expected, the rising of sea levels will affect the sector, as new investment will be needed to keep ports' operability. Under the high emissions scenario, it is expected that these costs could increase 2.8 million of euros per year until the end of the century (see **Figure 9.31**).

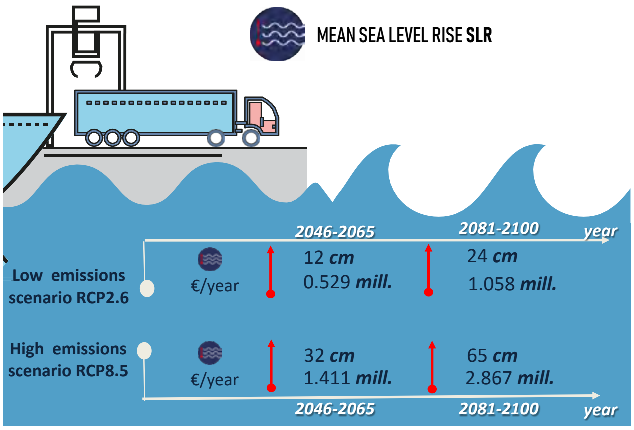


Figure 9.31. Increased costs for maintaining ports' operability in Malta under different scenarios of SLR caused by climate change until 2100.

Source: SOCLIMPACT Deliverable Report D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

9.6. Impacts on the Island' s Socio-Economic System

The aim of our study is to assess the socio-economic impacts of biophysical changes for the island of Malta. For this purpose, we have used the GEM-E3-ISL model, a single-region, multi-sectoral general equilibrium model based on the principles of neo-classical theory, and GINFORS, a macro-econometric model based on the principles of post-Keynesian theory.

Both models include 14 sectors of economic activity, with an emphasis on services and specifically on those composing the tourism industry. The GEM-E3-ISL model also includes an endogenous representation of labor and capital markets as well as bilateral trade flows by sector.

Changes in the mean temperature, sea level and precipitation rates are expected to affect energy consumption, tourism flows and infrastructure developments. These impact-chains have been examined and quantified under two emission pathways: RCP2.6, which is compatible with a temperature increase well below 2 °C by the end of the century, and RCP8.5, which is a high-emission scenario. The impact on these three factors was used as input in the economic models, which then assess the effects on GDP, consumption, investments, employment, etc.

In total, 17 scenarios have been quantified for Malta. The scenarios can be classified in the following categories:

1. Tourism scenarios: these scenarios examine the reduction in tourism revenues due to changes in human comfort as captured by the hum-index, the degradation of marine environment, the increased risk of forest fires and beach reduction. The aggregate tourism scenario (TOUR-SC6) assesses the economic impacts of a simultaneous change of all (the above-mentioned) factors.
2. Energy scenarios: the aggregate energy scenario (ENER-SC3) assessed the impacts on regional economic performance of increased total electricity demand driven by cooling and water desalination demand.
3. Infrastructure scenario: this scenario assesses the impact of port infrastructure damages (INFRA-MAR).
4. Aggregate scenarios: these scenarios examine the total impact of the previous-described changes in the economy.

In the aggregate scenario, we examine the impacts of a simultaneous change in electricity consumption, tourism revenues and infrastructure damages. The scenario specifications for the two climatic variants are presented below (see **Table 9.7**):

Table 9.7. Aggregate scenario –inputs.

	Tourism revenues (% change from reference levels)	Electricity consumption (% change from reference levels)	Infrastructure damages (% of GDP)
RCP2.6 (2045-2060)	-10.31	6.90	-0.26
RCP2.6 (2080-2100)	-14.19	4.20	-0.29
RCP8.5 (2045-2060)	-20.03	14.00	-0.69
RCP8.5 (2080-2100)	-33.42	25.70	-0.77

Source: SOCLIMPACT Deliverable Report D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

The theoretical and structural differences of the two models mean that this study produces a reasonable range of impacts, given the uncertainty embodied in economic analysis and especially in the long-term.

In GEM-E3-ISL, the economy is in equilibrium at each point in time. Prices adjust to ensure that supply equals demand (market clearing) and capital is fully used; however, the model allows for equilibrium unemployment as it takes into account labor market rigidities. The impacts are driven mainly by the supply side through changes in production costs which influence relative prices; hence, competitiveness and trigger substitution effects. The GEM-E3-ISL model assesses the impacts on the economy up to 2100.

The macro-econometric type of models, such as GINFORS, do not require that all markets are in equilibrium; idle capital and involuntary unemployment are some other features of this type of models where the results are driven mainly by adjustments in the demand side of the economy. The GINFORS assesses the impacts on the economy up to 2050.

With respect to GDP, the estimated change compared to the reference case is between -0.15% and -1.8% in the RCP2.6 in 2050 and between -0.55% and -4.0% in the RCP8.5. The cumulative change over the period 2040-2100 is estimated (by GEM-E3-ISL) to be equal to -0.2% in the RCP2.6 and -0.9% in the RCP8.5. The results are compatible with the structure of the Maltese economy, which is highly service-oriented but depends mainly on market services (e.g., financial services, consultant services etc.) rather than tourism related services (see **Figure 9.32**).

With respect to sectoral impacts, both models show a significant decrease in the activity of tourism related sectors and an increase in the activity of the manufacturing sector and to a lesser extent in the activity of the primary sectors of production (see **Figure 9.33**).

Overall, employment falls in the economy and especially in tourism related sectors following the slowdown in domestic activity. In GEM-E3-ISL, increases in employment in non-tou-

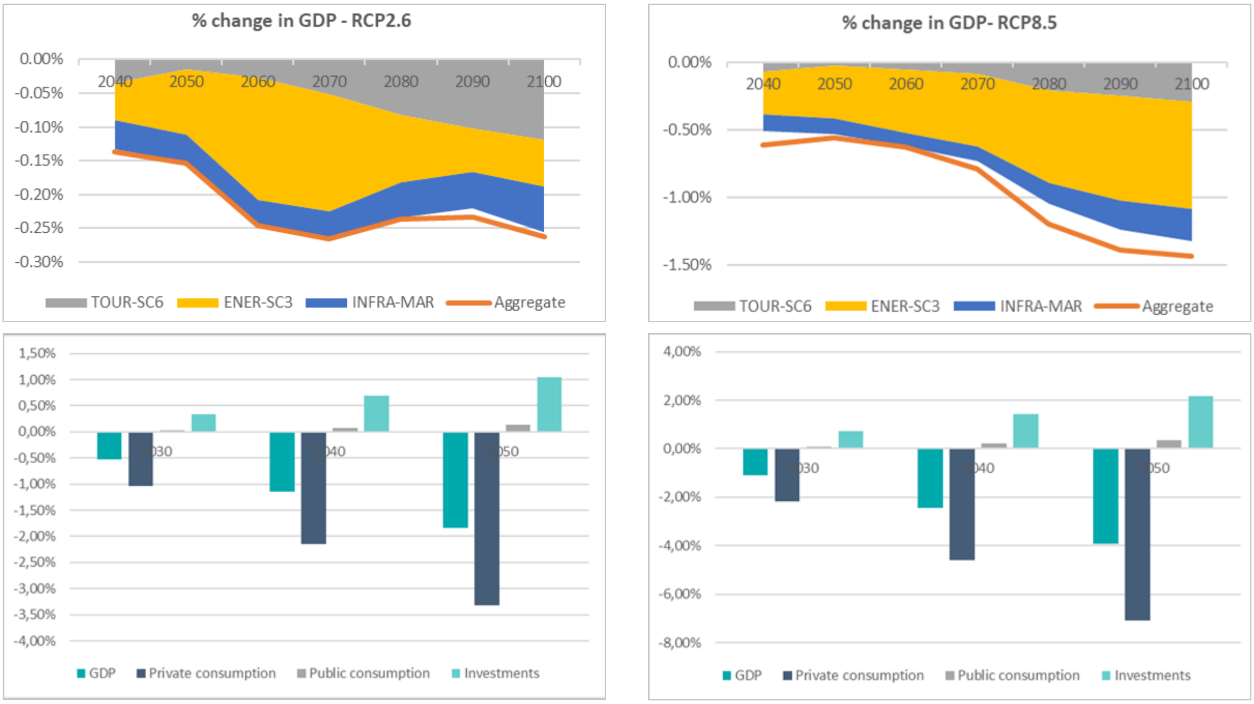


Figure 9.32. Percentage Change in GDP. GEM-E3-ISL results (above), GINFORS (below).

Source: own calculation.

Figure 9.33. Production percentage change from reference. GEM-E3-ISL results (above), GINFORS (below).

Source: own calculation.

rism related activities are related to labor costs reductions (as wages fall and their competitiveness increases) and a consequent substitution of capital with labor in other sectors. Employment falls on average by 0.02 % in both climatic variants. Employment is negatively affected by infrastructure damages and tourism reduction and positively affected by the increased investment for the expansion of electricity generation (see **Figure 9.34**).

Figure 9.34. Employment percentage change from reference. GEM-E3-ISL results (above), GINFORS (below).
Source: own calculation.

9.7. Towards Climate Resiliency

"Malta ratified the UNFCCC in 1994 and the Kyoto Protocol in 2001. Malta did not immediately take on any quantified emission limitation or reduction obligations under these international instruments; thus, it did not have a quantified target for the limitation or reduction of greenhouse gas emissions for the first Kyoto Protocol Commitment Period (CP1; 2008-2012)." (MRA, 2017). However, in 2010, Malta became an Annex I party to the UNFCCC which symbolized the intention of Malta to step up against climate change (MRA, 2017).

Malta also reports an annual national GHG inventory and other information at national and Union level relevant to climate change in line with the Monitoring Mechanism set out in EU Regulation No 525/2013 and needs to adhere to EU Emission Trading Scheme (EU Directive 2003/87/EC).

"Malta is committed to remain in line with the Effort Sharing Decision (Decision No. 406/2009/EC of 23 April 2009) thereby conforming to a reduction of its GHG emission growth by no more than 5 % on 2005 levels by 2020" (Ministry for Sustainable Development, the Environment and Climate Change, 2017).

Relevant National Documents

- Climate Action Act

This Act, adopted in 2015, provides for action in order to contribute to the mitigation of climate change by limiting anthropogenic emissions of greenhouse gases and protecting and enhancing greenhouse gas sinks and reservoirs. It also contributes to the prevention, avoidance and reduction of the adverse impacts of climate change and the reduction of vulnerability, enhancement of resilience, and adaptation to the adverse effects of climate change. It requires the ministry to review and update the national adaptation strategy every four years.

- Malta's National Strategy for Policy and Abatement Measures relating to the Reduction of Greenhouse Gas Emissions (MRRA, 2009)

This strategy, adopted in 2009, includes 96 actions for the period 2009-2020 to be adopted to reduce greenhouse gas emissions. Abatement measures are divided in four groups: energy, waste and agriculture, water and transport.

- National Climate Change Adaption Strategy (MRRA, 2012)

This strategy, adopted in 2012, recommends the necessary adaptation measures deemed relevant to sectors that are vulnerable to a changing climate through a set of 72 actions which addresses the following areas: agriculture, biodiversity, freshwater resources and coastal zones, land degradation, fisheries and migration. It also addresses issues related to financial impacts and sustainability. Six actions on tourism are included which focus mainly on research and one action to draw up a Tourism Action and Contingency plan. Adaption action plans were not developed due to the small size of the state. Malta is currently revising this strategy with the aim of including relevant adaptation policies. The new strategy is called the Low Carbon Development Strategy (2017) which is based on UN Framework Convention on Climate Change, Paris Agreement and Regulation (EU) NO 525/2013 of the European Parliament.

The following sector documents do consider adaptation issues (EC Country fiche for Malta):

- The 2nd Water Catchment Management Plan for the Maltese Islands (2016).
- The Malta National Biodiversity Strategy and Action Plan 2012-2020.
- The National Energy Efficiency Action Plan.
- The Malta's National Transport Master Plan 20259. adopted in 2016.
- The National Agricultural Policy for the Maltese Islands 2016-2025.

Specific limits and obstacles

Since the implementation of the Climate Adaption Strategy, adaption action has not been a primary focus for Malta's authorities. One reason for that can be the small size of the country which limits the range of issues that authorities can address (see here).

Additionally, Malta's number of inhabitants and cars on the island are increasing which results in the need to widen existing roads and build new ones. Little is done to curtail emissions from transport, which is one of the main contributors of GHG. This seems to jar with Malta's commitment to reduce greenhouse gas emissions and will make it difficult for the country to meet its emission targets (see here).

The rapidly increasing number of inhabitants on the island also triggers the boom of construction, which transforms more and more green areas into building sites which further limits the ability to absorb Carbon dioxide from the atmosphere.

There is an overall lack of subject-specific studies to estimate the impact and its costs of climate change and the required adaption (see here).

Effects of climate change on aquaculture activities include biological, environmental and socio-economic impacts and can be short- or long-term caused by f.e. changing temperature, oxygen availability and increased extreme weather events. Eventually, these impacts can lead to the loss of production and infrastructure. A strong focus should therefore be placed on building general adaptive capacity that supports the sector.

However, there is a lack of reliable statistics and information related to exposure and vulnerability of the island to climate change. These are important components that worsen climate risks and respond to human interventions (more pressure). The island' s adaptation focus should be, first, the development of reliable information systems for the periodic monitoring of these components.

9.7.1. Policy Recomendations

A stakeholders consultation process was carried out in the island, aiming to propose, analyse and rank alternative adaptation measures for the island. The profile of the individuals participating in these focal groups involved policy and decision-makers, practitioners, non-governmental and civil society organisations, science experts, private sector, business operators and sector regulators at island level.

The main aim of these meetings was:

1. Identify and present the characterized packages of adaptation and risk management options for the island.
2. Develop detailed integrated adaptation pathways in three timeframes: Short term (up to 2030), Mid-century (up to 2050) and End-century (up to 2100).
3. Evaluate and rank adaptation options for the aquaculture sector in the island.

To this aim, stakeholders utilized five evaluation criteria to rank the proposed measures:

- Cost efficiency: Ability to efficiently address current or future climate hazards/risks in the most economical way.
- Environmental protection: Ability to protect the environment, now and in the future.
- Mitigation win-wins and trade-offs: Current ability to meet (win-win) or not (trade-off) the island / archipelagos mitigation objectives.
- Technical applicability: Current ability to technically implement the measure in the island.
- Social acceptability: Current social acceptability of the measure in the island.

Four scenarios of intervention were analysed, called Adaptation Policy Trajectories, which are different visions of future policy adaptation choices:

- APT A Minimum Intervention - Low investment, low commitment to policy change.
- APT B Economic Capacity Expansion - High investment, low commitment to policy change.
- APT C Efficiency Enhancement - Medium investment, medium commitment to policy change.
- APT D System Restructuring - High investment, high commitment to policy change.

It was assumed that adapting to climate change may range from minimal to high cost, and from requiring a small or incremental change to a significant transformation from the *status quo*. However, not all APT scenarios were considered in all islands, especially when their stakeholders had a clear vision on the types of measures with greatest viability. Therefore, the final set of proposed adaptation measures are framed in the islands' socio-economic and political context, have a sectoral perspective, and respond to the islands' future scenarios of climate change. At the same time, the involvement of regional stakeholders in policy design allows them to engage in the effective implementation of climate actions on their island.

In Appendices from K to N, a brief explanation of each adaptation option can be found, classified by type or class: Vulnerability Reduction, Disaster Risk Reduction, Social-Ecological Resilience, and Local Knowledge. The latest group refers to very specific measures proposed by stakeholders in each island to ratify the needs.

9.7.1.1. Aquaculture

Overall, the adaptation pathways for the aquaculture sector in Malta are characterized by a significant heterogeneity across the four potential adaptation policy trajectories (APTs) and across adaptation objectives.

Under APT A Minimum Intervention (low investment, low commitment to policy change) efficient feed management, risk bases zoning and site selection and disaster risk management (prevention, protection, preparedness, response, recovery) were the most preferred measures by stakeholders. To improve Socio-Ecological Resistance, species selection is chosen, as it is more optimal and efficient than the feed production.

For APT B Economic Capacity Expansion (high investment, low commitment to policy change), tax benefits are more suitable for the short term, while for the medium- and long-term financial schemes insurance and loans are preferred. To improve socio-ecological resistance for the short term, a more sustainable feed production is preferred, while for mid and long term, species selection was the most selected measure. However, for APT A, species selection was chosen for the short term as well. This can be a strategy to diversify species in the short-term in order to choose species that are most efficient for aquaculture. Concerning regulating and maintenance services for all terms, better management practices were preferred over selective breeding.

In APT C Efficiency Enhancement (medium investment, medium commitment to policy change), again, efficient feed management was selected for short and long term. Moreover, the promotion of local consumption (reduce transport costs, create value addition) was preferred to address consumer and environmental concerns.

APT D System Restructuring (high investment, high commitment to policy change) has some similar results as other APTs. Efficient feed management was selected for short and mid-term, and climate proof aquaculture activities were chosen for the long term, since this measure requires high investment and high commitment. On the long term, when we might run out of other options, this could be a suitable measure. In the post disaster recovery class, for the short and long terms, plans were preferred, while for the mid-term funds were selected more often (see **Table 9.8**).

Table 9.8. Proposed adaptation options for aquaculture in Malta.

APT A – Pathway	**Short-term (up to 2030)**	**Mid-century (up to 2050)**	**End-of-century (up to 2100)**
Minimum Intervention low investment, low commitment to policy change — This policy trajectory assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts	Efficient feed management		
	Risk-based zoning and site selection		
	Mainstreaming Disaster Risk Management		
	Recovery Post-disaster plans		
	Species selection		

Table 9.8 (Cont.). Proposed adaptation options for aquaculture in Malta.

Pathway	Short-term (up to 2030)	Mid-century (up to 2050)	End-of-century (up to 2100)
APT B – Pathway — **Economic Capacity Expansion** high investment, low commitment to policy change — This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy	Tax benefits and subsidies	Financial schemes, insurance and loans	
	Efficient feed management		
	Recirculation Aquaculture Systems (RAS)	Submersible cages	
	Risk-based zoning and site selection		
	Feed production	Species selection	
	Best Management Practices		
APT C – Pathway — **Efficiency Enhancement** medium investment, medium commitment to policy change — This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system	**Short-term (up to 2030)**	**Mid-century (up to 2050)**	**End-of-century (up to 2100)**
	Efficient feed management	Awareness campaigns for behavioural change	Efficient feed management
	Promote cooperation to local consumption		Addressing consumer and environmental concerns at the local level
	Short-cycle aquaculture	Integrated multi-trophic aquaculture	
	Risk-based zoning and site selection		
	Environmental monitoring Early Warning Systems (EWS)		
	Feed production	Species selection	
	Best Management Practices		
	Promote aquaculture cuisine	Create educational visits	
APT D – Pathway — **System Restructuring** high investment, high commitment to policy change — This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems	**Short-term (up to 2030)**	**Mid-century (up to 2050)**	**End-of-century (up to 2100)**
	Tax benefits and subsidies	Financial schemes, insurance and loans	
	Efficient feed management		Awareness campaigns for behavioural change
	Short-cycle aquaculture	Integrated multi-trophic aquaculture	
	Risk-based zoning and site selection		Climate proof aquaculture activities
	Recovery Post-disaster plans		
	Species selection		

Vulnerability Reduction | *Disaster Risk Reduction* | *Socio-Ecological Resilience* | *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

Chapter

10

Sardinia (Italy)

SOCLIMPACT

This project has received funding from
the European Union's Horizon 2020 research
and innovation programme under
Grant Agreement No 776661

CONTENTS

Sardinia at a Glance

Sardinia is the second largest island in the Mediterranean after Sicily, covering an area of 29,949 km^2 and is located in the western part of Italy in the Tyrrhenian sea just to the south of the French island of Corsica (40°4′N 9°17′E). With a population of 1,648 million people, Sardinia is one of the least populated regions of Italy. Sardinia enjoys a certain autonomy compared to other regions and for that reason, on the Italian constitution, it is granted autonomous status. It is organised in provinces, municipalities and metropolitan cities, and the largest part of its population (around 50%) is concentrated in two major urban areas: Cagliari (capital of the island) with 560,000 inhabitants and Sassari with 331,000 inhabitants.

The Blue Economy Sectors

- **Aquaculture**

  As far as semi-intensive aquaculture is concerned, Sardinian companies are currently represented by facilities/plants for the breeding of valuable fish species both of salt and fresh water and of molluscs.

  Sardinia is still one of the leading Italian regions in marine fish production, with the greatest development potential both for quantitative as well as qualitative production.

  Despite the great availability of suitable sites to undertake the activity, fish farming in Sardinia has played a marginal role in the economy of the region until the late 1990s.

  The most recent farms are those set up at sea (offshore) in the 90s, adopting appropriate plant technologies that allow good integration with the surrounding environment.

  Among the fish, sea bream and sea bass are the two most important marine species bred.

- **Maritime Transport**

  Sardinian ports are responsible for 10% of the national cargo movement and 12% of total passenger movement, while activities tied to the maritime transport sector generate income equal to 5.3% of the regional gross value added (Banca Intesa and SRM, 2019). The port of Cagliari, which has the longest berths on the island, is the 'core' harbour of Sardinia in terms of infrastructure, equipment for loading and unloading of containers. Second for the available length of berths comes Porto Torres (North-West).

  The blue economy employs 42,300 people in Sardinia and 611 companies are active in the maritime cluster. To date, the greatest weakness of the Sardinian port system is represented by the excessive dependence on the oil sector.

  In 2018, the Management Committee of the Port System Authority of the Sardinian Sea unanimously approved the release of a 50-year state-owned maritime concession in favour of Edison Spa for the construction of a terminal for liquefied natural gas in the industrial port of Oristano.

- **Energy**

  Sardinia is interconnected to the Italian electricity grid. Electricity production reached 13 GWh in 2015 with the majority of the production facilities in the island being fossil-fuel powered (approximately 74%), which consisted of coal power plants (49%) and oil plants (51%). while a moderate share of electricity production comes from renewable sources (approximately 26%). The main source of renewable electricity is solar power (69%), as the island has an installed capacity of 732MW, followed by wind (26%) with an installed capacity of 1,028 MW, biofuels (3.3%) and hydro power (1%).

- **Tourism**

  The tourism industry contributes approximately 7% of the regional value added. The tourism attraction has grown at a relatively steady pace over the past twenty years. Sardinia records the second highest increase in tourism arrivals since 2000 among Mediterranean islands after Crete, along with the nights spent in the island.

  The main touristic attractions of the island, according to recent studies, are beaches (53%) followed by cultural sightings (19%) and tradition-related attractions (12%). The promotion of tourism is one of the main priorities of the regional authorities, and the short-term actions for this target are described in the "Piano Strategico di Sviluppo e Marketing TuristicodellaSardegna" (2018).

10.1. Current Climate and Risks

The climate of Sardinia is typically Mediterranean with mild temperatures throughout the year and short-li- ved winters. Sardinia is a windy island, especially from October to April when the mistral blows from North-West (France), whereas in spring and summer the prevailing winds blow from Africa, bringing warm and dry weather.

Rainfall is not abundant, in fact it ranges from 400 to 550 millimeters per year on the coast, and follows the Mediterranean pattern, since it is more common in autumn and winter. It decreases gradually in spring and reaches its lowest in summer, when it almost never rains.

The island is sheltered from cold waves; along the coasts and in the plains, snowfall is quite rate, but it can occur in the coldest winters, more frequently in the north of the region. When it comes to the effects of climate change on Sardinia, since the early '80s data reveal a warming trend confirmed by temperature extremes with an increase in the extremes of heat and a reduction of extremes of cold. The number of tropical nights per year has also been increasing.

The expected climate change signal is less clear for rain than for temperature. In fact, precipitation indices do not highlight an unequivocal change in the frequency and intensity of precipitation. However, a tendency (see **Figure 10.1**).

CURRENT CLIMATE-RELATED RISKS

- Coastal flood High
- Wildfire High
- River flood Medium
- Extreme heat Medium

SIGNIFICANT CLIMATE EVENTS

- Storm torrential rains (December 2008)
- Flood torrential rains (October 2018)

CLIMATE CHARACTERISTICS (40°N 9°E, 384m asl)

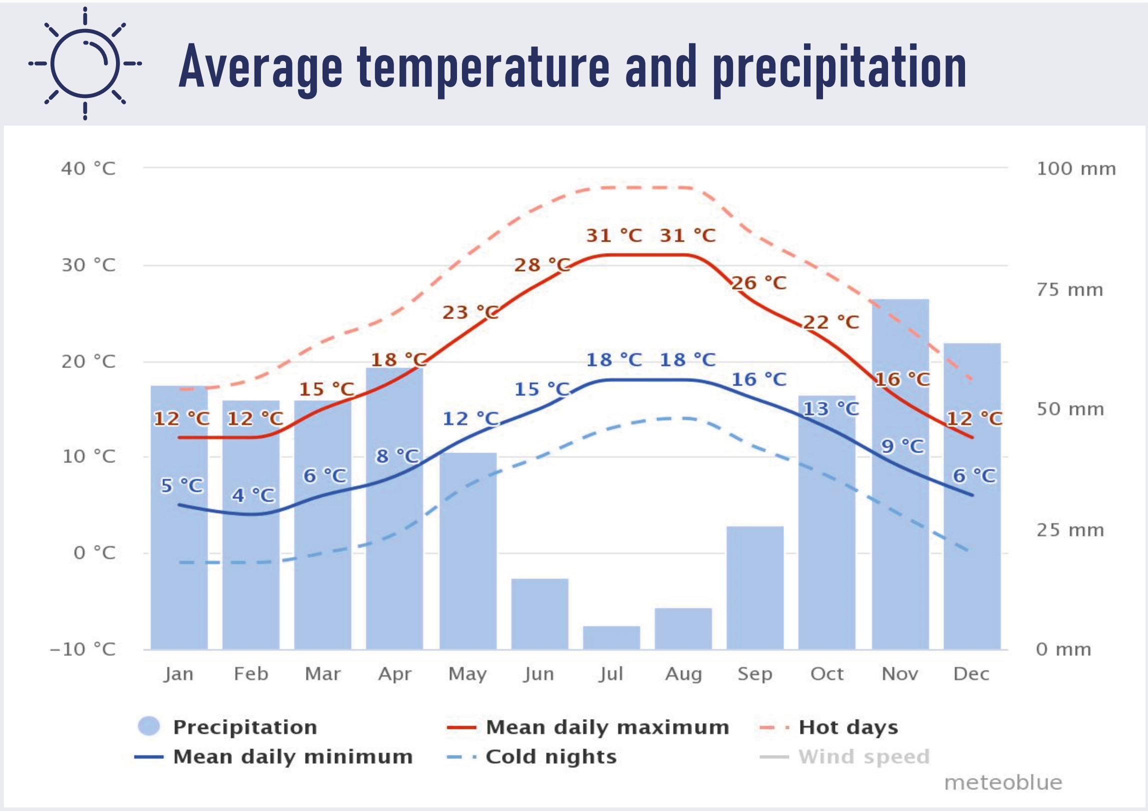
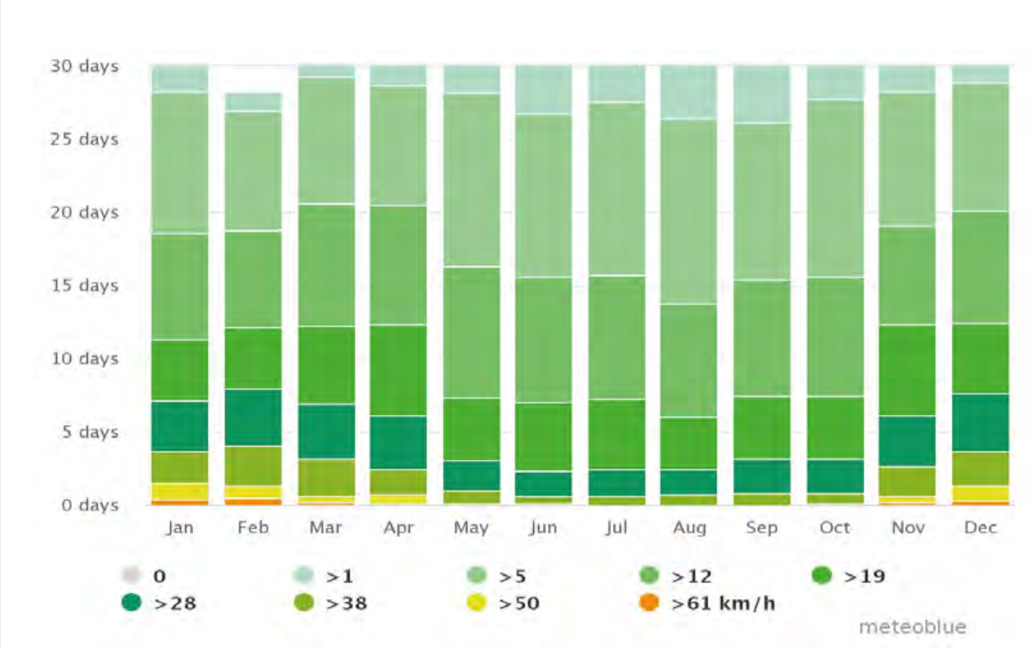


Figure 10.1. Climate factsheet.

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System). **(Continued on the next page)**

Wind speed



Cloudy, sunny and precipitation

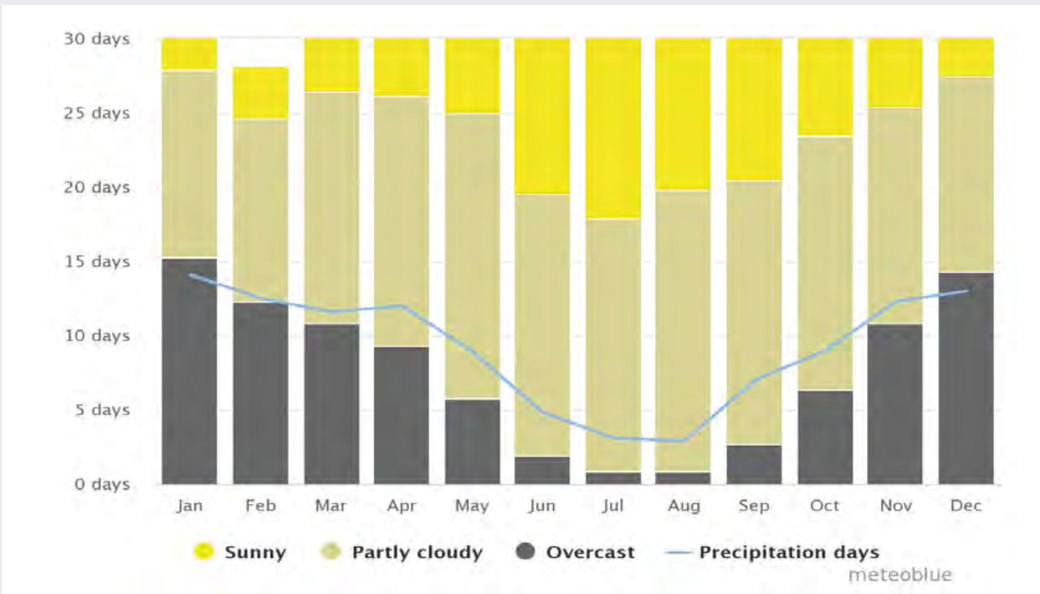


Figure 10.1 (Cont.). Climate factsheet.

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System). ***(Continued on the next page)***

Wind rose

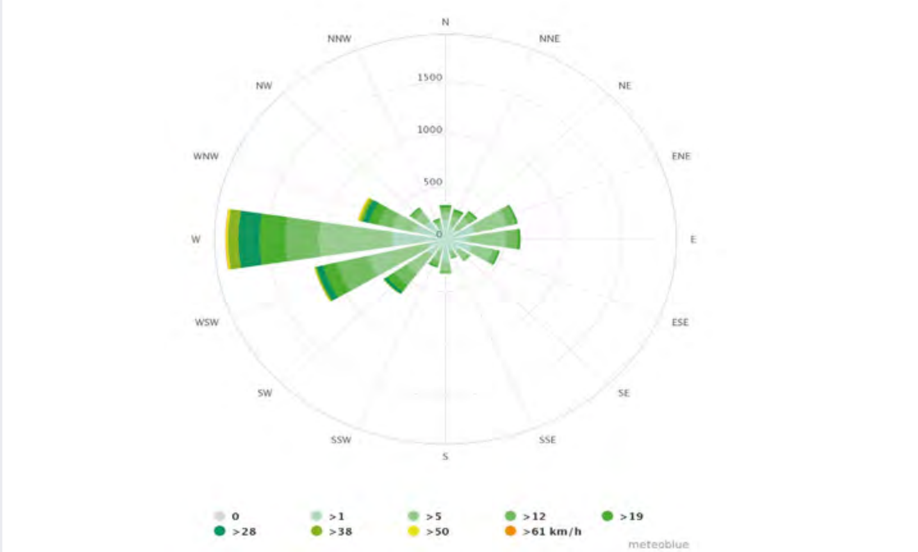


Figure 10.1 (Cont.). Climate factsheet.

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System).

10.2. Macroeconomic Projections

Based on the projections, Sardinia is expected to grow with an average annual rate of 0.9% throughout the 2015-2100 period and with 0.6% throughout the 2015-2100 period. The main driver of growth throughout the period is the improvement of the island's competitiveness, which is supported by increased investments (see **Table 10.1** and **Figure 10.2**) that lead to a decrease of the regional trade deficit. Trade deficits are projected to decrease to around 9.5% of the regional GDP compared to the trade deficits of 2015 of 17.9% of the Sardinian GDP. Still, Sardinia remains a net importer in 2100. Investments grow with a high pace over the whole projected period, reflecting the increased funding requirements of the economy. We assume that the share of public

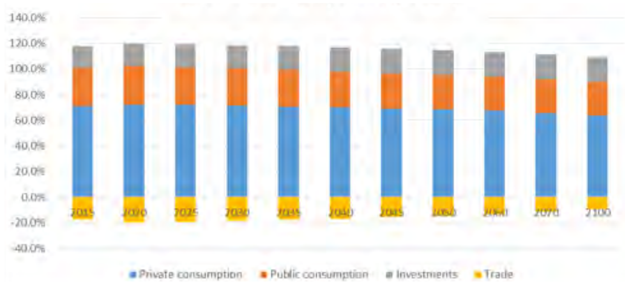


Figure 10.2. Macroeconomic components as a% share of GDP for Sardinia in 2015-2100.

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

Table 10.1. Sardinia GDP and GDP components yearly growth rates in 2020-2100.

	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
GDP	0.0%	0.5%	0.4%	0.6%	0.6%	1.0%	1.1%	1.5%	1.4%	0.9%
Private consumption	0.2%	0.5%	0.3%	0.4%	0.5%	0.8%	0.9%	1.3%	1.1%	0.8%
Public consumption	0.4%	0.1%	0.0%	0.2%	0.2%	0.6%	0.7%	1.3%	1.3%	0.9%
Investments	1.1%	0.7%	0.6%	1.1%	1.1%	1.2%	1.3%	1.6%	1.4%	0.9%
Exports	0.0%	1.2%	0.3%	0.6%	-0.1%	1.9%	-0.3%	-0.2%	-0.6%	0.9%
Imports	0.4%	1.0%	0.2%	0.4%	-0.1%	1.5%	-0.3%	-0.2%	-0.6%	0.8%

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

consumption slightly decreases until 2100; nevertheless, per capita public consumption expenditures increase over the time period under consideration.

10.2.1. The Sectoral Projections

The Sardinian economy remains a service-led economy throughout the 2015-2100 period. Market and non-market services remain the largest activities in the Sardinian economy, but during this period, there is a clear reorientation from traditional public related activities towards market-oriented activities. Other sectors that are expected to record higher relative growth are the construction sector (+1.4% relative to 2015), which benefits more from the increased investment expenditures, the consumer goods industries (+1.3%), and to a lesser extent the accommodation and food services sector (+0.3%) (see **Figure 10.3**).

The accommodation and food service sector are projected to slightly increase its contribution to the regional economy reflecting the moderate increasing pace of tourist arrivals in the island, and the same trend is projected for the consumer goods industry which is mainly made up of food products and is linked to tourism activity through the wholesale trade and restaurants activities. For the maritime sector, the relatively small projected growth rates are associated mainly to the decrease of freight transport activity with the reduction on imports and the diversification of the economy (see **Table 10.2**).

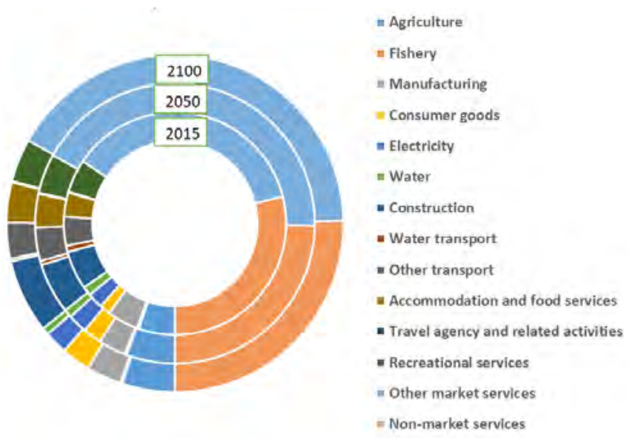


Figure 10.3. Sectoral value added as a% share to total GVA for Sardinia in 2015, 2050 and 2100.

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

Table 10.2. Sectoral contribution as a% share of total gross value added for Sardinia in 2015-2100.

GVA% shares	2015	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
Agriculture	5.3%	5.3%	5.3%	5.3%	5.6%	5.5%	5.6%	5.6%	5.5%	5.4%	5.1%
Fishery	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Manufacturing	4.6%	3.8%	3.7%	3.5%	3.6%	3.3%	3.3%	3.2%	3.0%	3.1%	3.4%
Consumer goods	1.5%	1.9%	1.8%	1.8%	1.9%	2.0%	2.0%	2.2%	2.4%	2.7%	2.8%
Electricity	2.2%	2.2%	2.2%	2.2%	2.3%	2.2%	2.3%	2.2%	2.2%	2.1%	2.2%
Water	1.4%	1.2%	1.2%	1.1%	1.1%	1.0%	1.0%	0.9%	0.8%	0.8%	0.7%
Construction	5.6%	5.3%	5.3%	5.3%	5.5%	5.6%	5.6%	5.8%	6.4%	7.1%	7.1%
Water transport	0.9%	0.8%	0.7%	0.7%	0.7%	0.6%	0.5%	0.5%	0.4%	0.3%	0.3%
Other transport	4.2%	4.2%	4.2%	4.1%	4.2%	4.0%	4.0%	3.9%	3.7%	3.5%	3.4%
Accommodation and food services	3.5%	3.7%	3.8%	3.8%	3.8%	3.9%	3.9%	3.9%	3.8%	3.7%	3.9%
Travel agency and related activities	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Recreational services	4.8%	5.0%	4.9%	4.8%	4.8%	4.7%	4.7%	4.6%	4.5%	4.4%	4.2%
Other market services	36.6%	38.1%	39.4%	40.3%	40.1%	41.2%	41.7%	42.1%	41.9%	40.9%	41.5%
Non-market services	28.9%	27.9%	27.2%	26.6%	26.2%	25.6%	25.0%	24.8%	25.1%	25.6%	25.2%

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

10.2.2. Employment

Economic growth brings positive effects to the labor market with unemployment projected to fall from 17.4% in 2015 to more sustainable levels until 2050 (8.2%). The contribution of each sector to total employment depends on the labor intensity of the sector. The biggest employing sectors are the market/non-market services and manufacturing employing 66.3% of the total working population in 2015, while the share of labor employed in agriculture is 6.1%. The latter is expected to decrease over the period examined mainly due to the adoption of more efficient cultivation methods and the automation of agricultural production. The employment in the construction sector is projected to increase from 6.5% to 7.7% due to the increased investment levels foreseen over the whole projection period for the modernization of the production facilities. Service-related employment increases from 53.4% in 2015 to 60.7% in 2100 (see **Table 10.3** and **Figure 10.4**).

Table 10.3. Unemployment rate for Cyprus in 2020-2100.

	2015	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
Unemployment rate	17.4%	15.0%	13.5%	12.1%	11.6%	10.2%	9.4%	9.5%	9.2%	8.3%	8.2%

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

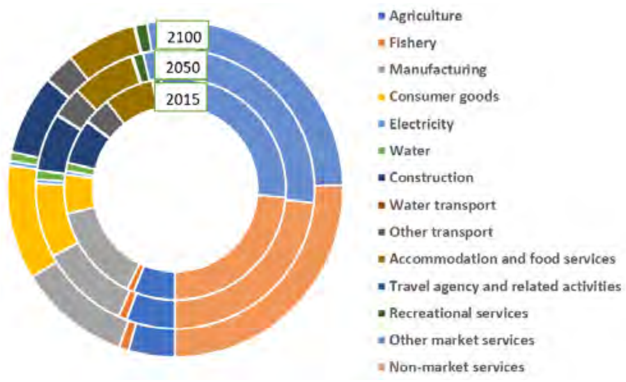


Figure 10.4. Sectoral employment as a% share of total for Sardinia in 2015, 2050, 2100.

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

10.3. Climate Change Outlook

Climate hazards indicators represent the entry point to understand the climate change exposure of the blue economy sectors. The indicators have been computed for two scenarios, RCP2.6 (low emission scenario) and RCP8.5 (high emission scenario) and for different horizon times namely: a reference period (1965-2005), mid-century (2046-2065) and end of century (2081-2100). Main source of climate projections (future climate) for Sardinia is EURO-CORDEX ensemble even if other model sources were applied when required, depending of available scales. Results are presented in form of maps, tables or graphs and only when the information shows an interesting outcome.

10.3.1. Tourism

10.3.1.1. Beach flooding and related losses

One of the consequences of an increase in the mean sea level will be the flooding of coastal areas. This includes sand beaches, which are the main asset for tourism activities in most of the European islands. Therefore, estimating the potential risk of beach loss due to climate change is of paramount importance for the economy of those islands. The 95th percentile of the flood level averaged was selected as an indicator of interest. The values are presented as anomalies with respect to the present mean sea level at beach location (i.e., including the median contribution of runup). In all cases, an increase is expected to be larger at the end of the century under scenario RCP8.5. The value of extreme flood levels in that scenario is 92.47 cm in Sardinia. Under mean conditions, we find that, at the end of century, the total beach surface loss range from ~46% under scenario RCP2.6 to ~77% under scenario RCP8.5 (see **Figure 10.5**).

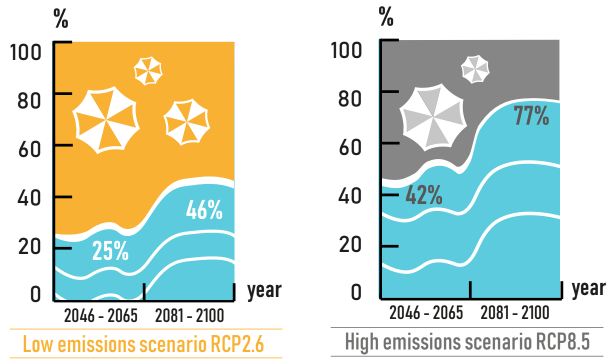


Figure 10.5. Beach reduction (%).

Source: SOCLIMPACT project deliverable D4.4d - Report on the evolution of beaches.

10.3.1.2. Seagrass evolution

Seagrasses are the main habitat for coastal marine ecosystems. They provide different services like sediment retention (and thus, clearer waters), coastal protection (in front of marine storms), shelter for marine organisms, etc. Therefore, the state of the seagrasses is a convenient proxy for the state of coastal environment. That is, large well-preserved extensions of seagrasses lead to a better coastal marine environment which in turn is more resilient in front of hazards. Our results suggest that no seagrass losses are expected for the Posidonia located in the coasts of Sardinia island, except under the scenario 8.5 at the end of century (loss of 14.4%) (see **Figure 10.6**).

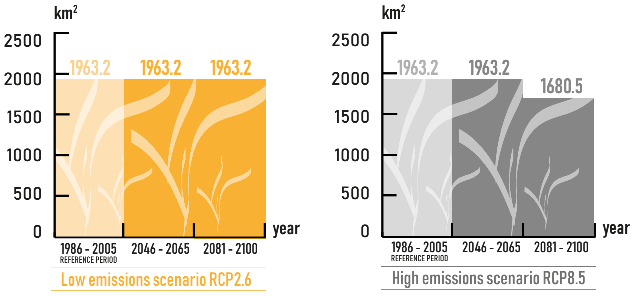


Figure 10.6. Seagrass evolution.

Source: SOCLIMPACT Deliverable [Report - D4.4e](). Report on estimated seagrass density.

10.3.1.3. Length of the window of opportunity for vector-borne diseases

Vector Suitability Index for Aedes Albopictus (Asian Tiger Mosquito)

Climate change can influence the transmission of vector-borne diseases (VBDs) through altering the habitat suitability of insect vectors. This is mainly controlled by increases of ambient air temperature and changes in the hydrological cycle. We explore if potential changes to meteorological conditions can affect the distribution of the Asian tiger mosquito (Aedes albopictus). Asian tiger mosquito is native to the tropical and subtropical areas of Southeast Asia; however, in the past few decades, this species has spread to many countries through the international transport of goods and increased travel (Scholte and Schaffner, 2007). It is of great epidemiological importance since it can transmit viral pathogens and infectious agents that cause chikungunya, dengue fever, yellow fever and various encephalitides (Proestos *et al.,* 2015).

The multi-criteria decision support vector distribution model of Proestos *et al.* (2015) has been employed to estimate the regional habitat suitability maps. This is based on extending previous work on the environmental/climatic factors affecting the life cycle of the Asian tiger mosquito (Waldock *et al.,* 2013; Proestos *et al.*, 2015). The mosquito habitat suitability model combines seven meteorological indices based on field observations, extensive literature review and expert knowledge.

Sardinia is found to have high habitat suitability index values for the simulations of the present climate. This is also verified by the fact that populations of Aedes Albopictus have already been reported in this island. Slight increases and decreases of the HSI values are projected for simulations under RCP2.6 and RCP8.5, respectively. The decreases are mainly found to be in the interior of the island (not showed) where the higher increases of temperature are expected to occur in a warmer future (see **Figure 10.7**).

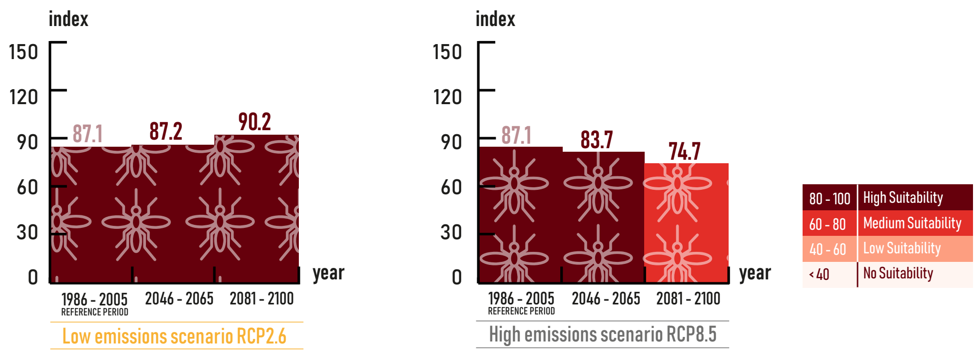


Figure 10.7. Habitat Suitability Index (HSI). [80-100: High Suitability; 60-80: Medium Suitability; 40-60: Low Suitability; <40 No Suitability].

Source: SOCLIMPACT Deliverable [Report - D4.3](). Atlases of newly developed hazard indexes and indicators.

10.3.1.4. Fire Weather Index (FWI)

The FWI system provides numerical, non-dimensional ratings of relative fire potential for a generalized fuel type (mature pine stands) based solely on weather observations. FWI is part of the Canadian Forest Fire Danger Rating System established in Canada since 1971 (van Wagner, 1987). Furthermore, since 2007, FWI has been adopted at the EU level and used in a harmonized way throughout Europe by the European Forest Fire Information System (EFFIS) of the Copernicus Emergency Management Service (since 2015).

It is selected for exploring the mechanisms of fire danger change for the islands of interest, as it has been proved to adequately perform for several locations, including the Mediterranean basin.The index was calculated for the fire season (defined from May to October) over the Mediterranean for all models, scenarios and periods.

For Sardinia, N = 185 grid cells were retained from the models domain. In the following figure, the ensemble mean and the uncertainty is presented for all periods and RPCs. While the most areas exhibit very and low fire danger in the present climate and under RCP2.6 for the near and the distant future as well. It seems that under RCP8.5, many areas cross over into medium fire danger, while increases towards the end of the century there are areas mainly inland that exhibit high fire danger. The overall increase exceeds 40 %. For RCP2.6, we find the highest uncertainty for the near future period, which decreases substantially at the end of the century, indicating that the projections become more robust (see **Figure 10.8**).

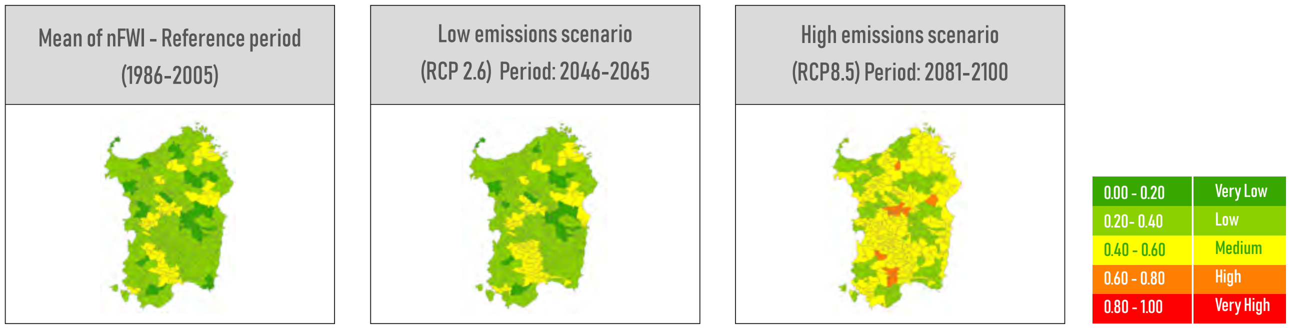
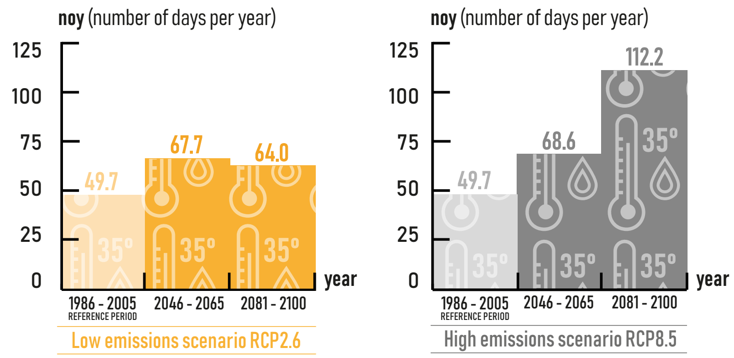


Figure 10.8. Fire Weather Index (EURO-CORDEX) with the color associated to the nivel of risk.
Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed hazard indexes and indicators.

10.3.1.5. Humidex

For the assessment of climate hazard on heat related impacts of climate change on human health, the humidity index (Humidex) (Masterton and Richardson, 1979) has been used. Humidex value is an equivalent temperature, which express the temperature perceived by people (the one that the human body would feel), given the actual air temperature and relative humidity. As a more representative indicator for the assessment of inhabitants' and tourists' hazard on heat related climate change impacts, the number of days with Humidex greater than 35 °C was selected. From the above classification, a day with Humidex above 35 °C describes conditions from discomfort to imminent danger for humans.

For Sardinia, N = 185 grid cells were retained from the models domain. In the following figure, the ensemble mean and the uncertainty is presented for all periods and RPCs. From less than 2 months in the present climate and quite above 2 months in the mid-century for both scenarios, Sardinia will have almost 4 months with discomfort conditions by the end of the century under RCP8.5 (see **Figure 10.9**).



HUMIDITY	INDEX-DISCOMFORT LEVEL
<29°C	comfortable
30-34°C	some discomfort
35-39°C	discomfort; avoid intense exertion
40-45°C	great discomfort; avoid exertion
46-53°C	significant danger; avoid any activity
>54°C	imminent danger; heart stroke.

Figure 10.9. Number of days per year with Humidex > 35° C (Euro-CORDEX).
Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed indexes and indicator.

10.3.2. Aquaculture

The predicted impacts of climate change on the oceans and seas of the planet are expected to have direct repercussions on marine based aquaculture systems. The basic effects are the following (Soto and Brugere, 2008):

- Increased invasions from alien species.
- Increased spread of diseases.
- Changes in the physiology of the cultivated species by changing temperature, salinity, oxygen availability and other important physical water parameters.
- Changes in the differences between sea and air temperature, which will alter the seasonality, frequency and severity of storms, cyclones and other extreme events, affect the stability of the coastal resources and potentially increase the damages in infrastructure.
- Sea level rise, acidification, changes in precipitation and other effects will also add to the changes in coastal ecosystems and environment, thus affecting production and infrastructure (=investments).

Temperature changes in seawater trigger physical impacts such as increased harmful algal blooms, decreased oxygen level, increase in diseases and parasites, changes in ranges of suitable species, increased growth rate, increased food conversion ratio and more extended growing season. Furthermore, all these impacts lead to socio-economic implications among them, like changes in production levels and an increase in fouling and pests. The objective of the current analysis is to identify and quantify the variations (future climate scenarios with respect to present climate) in the number and in the duration of events characterized by a Sea Surface Temperature (SST) exceeding a given threshold. The SST thresholds have been identified according to the farming and feeding necessities of several marine species, particularly relevant for the aquaculture sector in the Mediterranean Sea (MS) (see **Figure 10.10**).

	Longest event (days) >20 degrees Mussels & clams	Longest event (days) >24 degrees Sea bream/Tuna	Longest event (days) >25 degrees Sea bass
Historic (1986-2005)	123 days	31 days	16.5 days
RCP 8.5 - mid century	149.5 days	61.5 days	42 days
RCP 8.5 - end century (2081-2100)	178.5 days	90.5 days	67 days

Species	Threshold (°C)
European seabass, Dicentrarchus labrax	25
Gilthead seabream, Sparus aurata	24
Amberjack, Seriola dumerili	23
Atlantic Bluefin tuna, Thunnus thynnus	23
Japanese clam, Ruditapes decussatus	21
Blue mussel, Mytilus edulis	21
Manila clam, Rudtape philippinarum	20
Mediterranean mussel, Mytilus galloprovinciales	20

Figure 10.10. Number of days per year exceeding a given threshold.

Source: SOCLIMPACT Deliverable Report - D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

10.3.3. Energy

10.3.3.1. Cooling Degree Days (CDD)

The Cooling Degree Days (CDD) index gives the number of degrees and number of days that the outside air temperature at a specific location is higher than a specified base temperature, providing the severity of the heat in a specific time period taking into consideration outdoor temperature and average room. For Sardinia, at the end of century, under RCP8.5., the increase of number of days is amount the triple of the hindcast (see **Figure 10.11**).

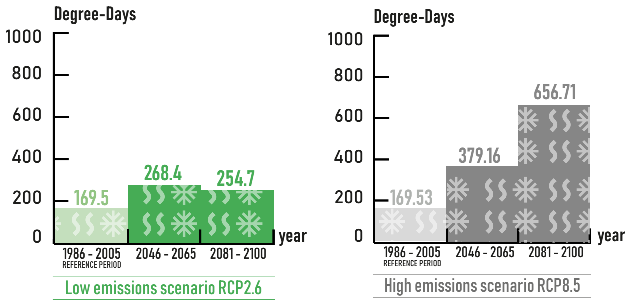


Figure 10.11. Cooling Degree Days. Ensemble mean of EURO-CORDEX simulations.

Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed hazard indexes and indicators with Appendices.

10.3.3.2. Available water: Standardized Precipitation Index

This index is used as an indication of water availability. For Sardinia, only some regions of the north-east of the island are expected to be affected under RCP2.6 and exceed the "dry" conditions threshold. Under the business-as-usual RCP8.5 forcing, parts of the island are expected to experience extreme dry conditions that will be evident even from the mid 21st century. Mild changes are projected under RCP2.6, while under the business-as-usual scenario the whole island is expected to be severely affected by meteorological droughts (see **Figure 10.12**).

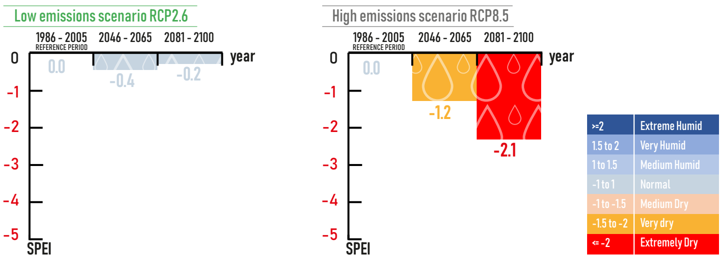


Figure 10.12. Ensemble mean values of the Standardized Precipitation Evaporation Index (SPEI) averaged.

Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed hazard indexes and indicators with Appendices.

10.3.4. Maritime Transport

10.3.4.1. Sea Level Rise (SLR)

Sea Level Rise (SLR) is one of the major threats linked to climate change. It would induce permanent flooding of coastal areas with a profound impact on society, economy and environment. Moreover, an increase in the mean sea level would result in a larger impact of coastal storms with the consequent increase of risk. The results are presented in terms of mean sea level rise. For Sardinia, the SLR ranges from 22.19 cm (RCP2.6) to 60.46 cm (RCP8.5) at the end of the century (see **Figure 10.13**).

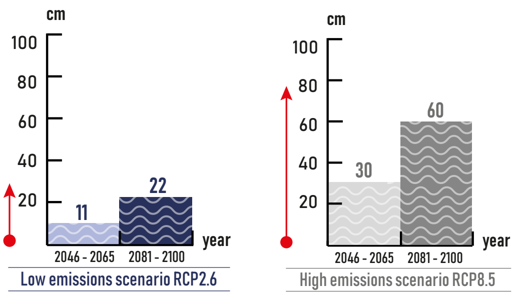


Figure 10.13. Mean sea level rise (in cm) with respect to the reference period (1986-2005). Own elaboration based on global and regional simulations.

Source: SOCLIMPACT Deliverable Report - D4.4b. Report on storm surge levels.

populated with enough number of members to compute meaningful statistics on climate projections is the one produced for the Mediterranean by Lionello *et al.* (2017). This ensemble consists on 6 simulations run with the HYPSE model at 1/4° of spatial resolution and forced by the high-resolution wind fields from the MedCORDEX ensemble, which in turn is nested into CMIP5 global simulations. The simulations are run for the period 1950-2100, thus covering the historical period as well as the whole 21st century. Complementary, the ensemble includes three hindcast simulations that are used to establish present reference levels. The results show a low decrease except for RCP8.5 at the end of the century (see **Figure 10.14**).

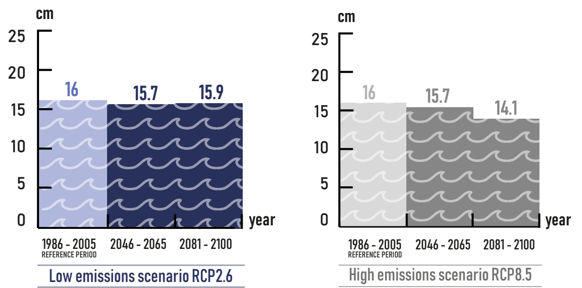


Figure 10.14. 99th percentile of atmospherically forced sea level (in cm) averaged for the hindcast period, the near future (2046-2065) and the far future (2081-2100) under scenarios RCP2.6 (with scaling approximation) and RCP8.5 (relative change in %).

Source: SOCLIMPACT Deliverable Report - D4.4b. Report on storm surge levels.

10.3.4.2. Storm surge extremes

Storm surge events, characterized by positive extreme sea levels and mechanically forced by atmospheric pressure and wind, are the main responsible for coastal flooding, especially when combined with high tides. To date, the only ensemble

10.3.4.3. Wind extremes

The wind extremity index NWIX98 is defined as the number of days per year exceeding the 98th percentile of mean daily wind speed. This number decreases in the far future under RCP8.5 (- 15.9%) (see **Figure 10.15**).

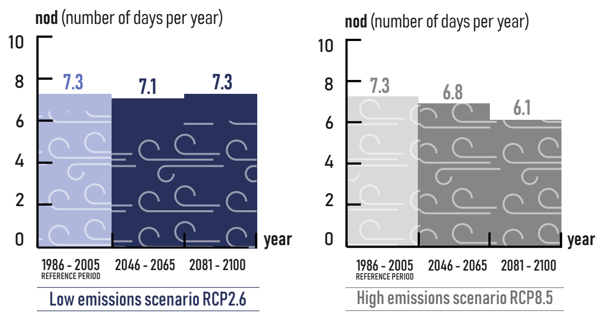


Figure 10.15. Wind Extremity Index (NWIX98). Ensemble mean of the EURO-CORDEX simulations.

Source: SOCLIMPACT Deliverable Report - D4.3. Atlases of newly developed indexes and indicator.

10.3.4.4. Wave extremes (99th percentile of significant wave height averaged)

Marine storms can have a negative impact on maritime transport, coastal-based tourism and aquaculture, among other activities. To illustrate this impact, the 99th percentile of significant wave height averaged has been chosen. A decrease in the extreme wave height is found being larger under scenario RCP8.5 as illustrated in the following map, more significantly in the West coast of the island. The more significant change is observed under RCP8.5. at the end of century with -3% (see **Figure 10.16**).

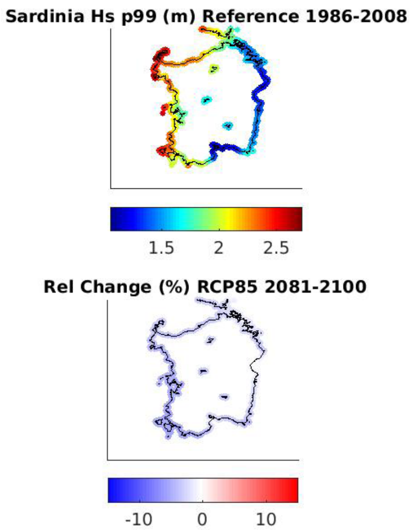


Figure 10.16. The 99th percentile of significant wave height averaged for the reference period and the relative change for the RCP8.5. Own elaboration based on global and regional simulations

Source: SOCLIMPACT Deliverable Report - D4.4b. Report on storm surge levels.

10.4. Risk Assessment

10.4.1. Tourism

10.4.1.1. Loss of comfort due to increase of thermal stress

As explained above, Sardinia scores the highest for exposure among all the analysed islands, contributing this criterion 62.9% to the total score. This is due to both tourists' arrivals and vulnerable groups. On the other hand, it is one of the islands at the lowest risk of loss of competitiveness due to thermal discomfort because of its exposure and adaptive capacity.

The mentioned advantages and disadvantages of Sardinia are depicted in the next figure. The further the criteria or sub-criteria is located from the centre of the graph, the more it affects the risk (see **Figure 10.17** and **Figure 10.18**).

The operationalization of the impact chain for the "Loss of attractiveness of a destination due to a decrease in thermal comfort" was conducted using the AHP method. The method proved to be appropriate, firstly, for dealing with the hierarchical nature of the impact chain and, secondly, for using expert judgements to assess the comparative risk for the islands over a large number of indicators (sub-criteria). Because the AHP method determines a ranking of the islands, it can provide decision-makers with relative values but not with absolute values.

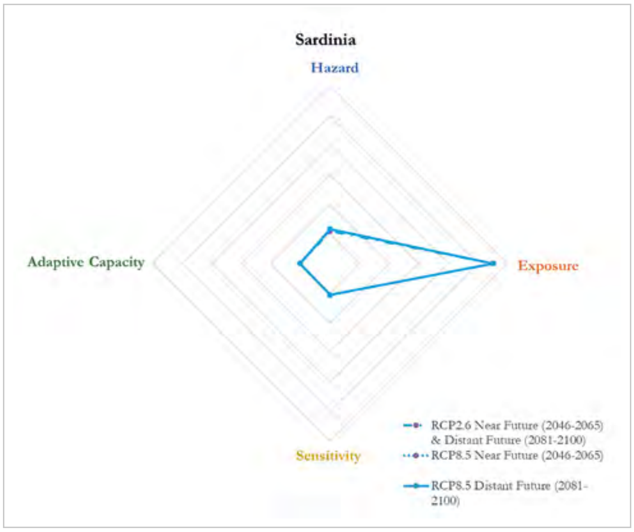


Figure 10.17. Global weights of each criteria and sub-criteria in the final score.

Source: SOCLIMPACT Deliverable Report – D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

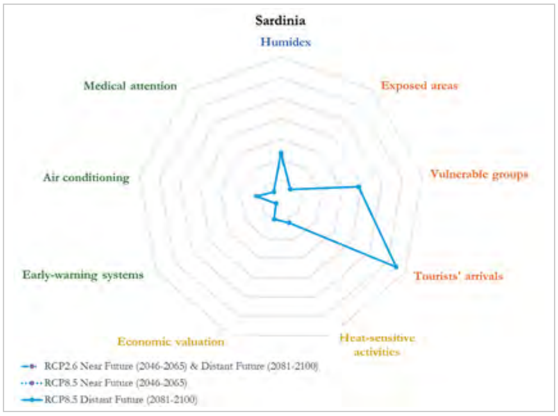


Figure 10.18. Global weights of each criteria and sub-criteria in the final score.

Source: SOCLIMPACT Deliverable [Report – D4.5](). Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

10.4.1.2. Loss of attractiveness due to increased danger of forest fires in touristic areas

For the reference period (1986-2005), the overall risk of forest fires is low for Sardinia. It is maintained low in the near future (2046-2065) for both RCPs and even for RCP2.6 in the distant future (2081-2100). However, for RCP8.5 in the distant future, it moves to an overall medium risk of forest fires. This is mainly due to the increase of fire danger (hazard) for the end of the century and a high vulnerability due to one of the highest's scores of flammability index (see **Figure 10.19** and **Figure 10.20**).

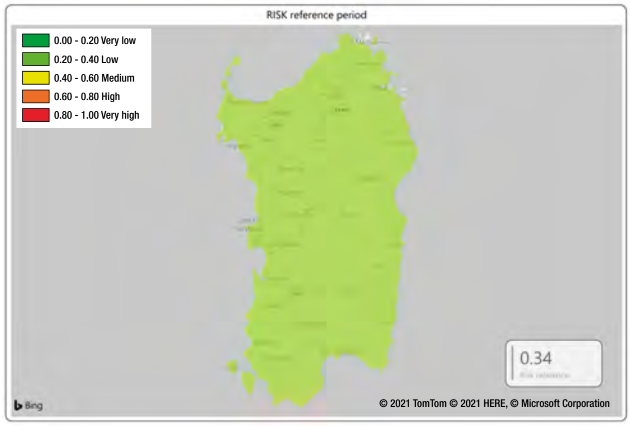


Figure 10.19. Risk score for the reference period.

Source: SOCLIMPACT Deliverable [Report – D4.5](). Comprehensive approach for policy makers.

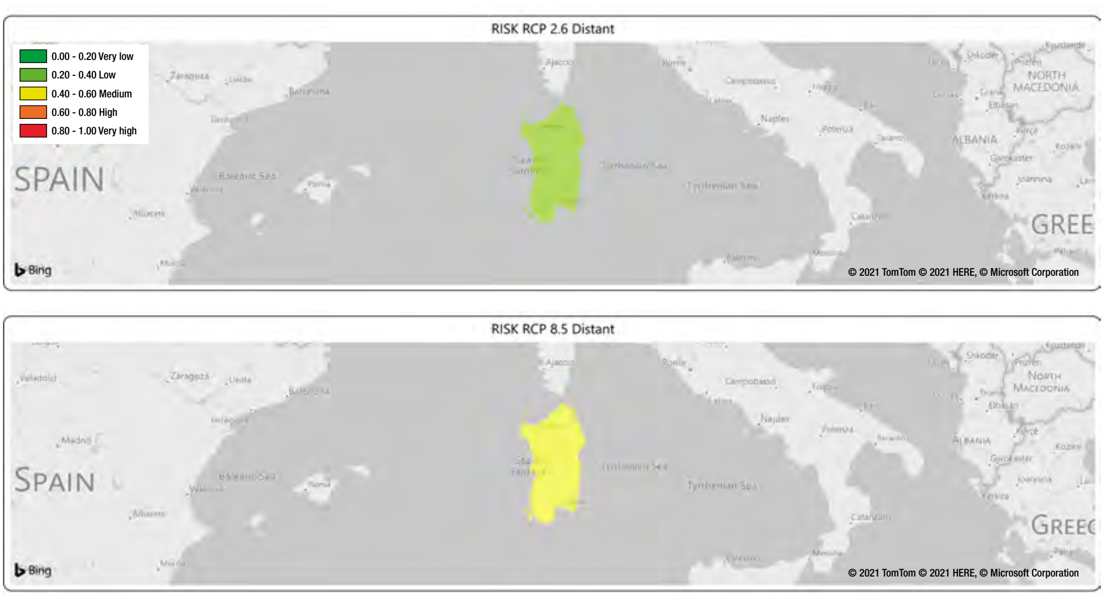


Figure 10.20. Risk score at the end in the distant future (2081-2100) under RCP2.6 (Ambitious Mitigation Policies) and RCP8.5 (Business as usual).

Source: SOCLIMPACT Deliverable [Report – D4.5](). Comprehensive approach for policy makers.

10.4.1.3. Risk of increased fragility of aquaculture activity due to extreme weather events

Results for the hazard induced by mean wave motion appear to classify most Mediterranean offshore farm locations as semi-exposed sites (unlike those in the Atlantic, which are offshore). The probability of occurrence of extreme events that might prove unendurable for infrastructures moderately lowers the cumulative hazard. Results for Sardinia appear to be stable across time horizons and scenarios, probably due to the Atlantic winds being well captured by the atmospheric modelling chain (see **Table 10.4**).

Table 10.4. Risk results for impact chain "Extreme Weather Events" for the Mediterranean islands.

Risk	Best-case scenario					Worst-case scenario				
	Reference period	Mid century		End century		Reference period	Mid century		End century	
	Hist	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	Hist.	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Corsica	0.19	0.19	0.19	0.20	0.21	0.25	0.25	0.26	0.28	0.26
Cyprus	0.23	0.23	0.23	0.23	0.22	0.23	0.23	0.23	0.23	0.22
Malta	0.26	0.26	0.26	0.26	0.26	0.42	0.45	0.56	0.45	0.36
Sardinia	0.30	0.32	0.32	0.28	0.31	0.33	0.33	0.34	0.33	0.33
Sicily	0.20	0.20	0.20	0.20	0.20	0.30	0.34	0.33	0.33	0.26

10.5. Impacts on the Blue Economy Sectors

10.5.1. Tourism (Non-Market Analysis)

In order to understand the effect of climate change on tourists behavior, a representative sample of 2538 European citizens have been interviewed in their countries of origin. Through online surveys, tourists were asked how climate change impacts can affect their travelling decisions and the islands' destination choice (see **Figure 10.21**).

The technique of Discrete Choice Experiments (DCEs) was implemented. This technique has been widely applied to the evaluation of tourists' preferences both in natural areas and other tourism contexts (e.g., Eymann and Ronning, 1997). It involves asking tourists to choose between alternative profiles or sets of attributes of the tourist destinations. The principal advantage of this method is that it allows researchers to investigate the preferences of various attributes of the tourist product simultaneously.

DCEs consist of several choice sets, each containing a set of mutually exclusive hypothetical alternatives between which respondents are asked to choose their preferred one.

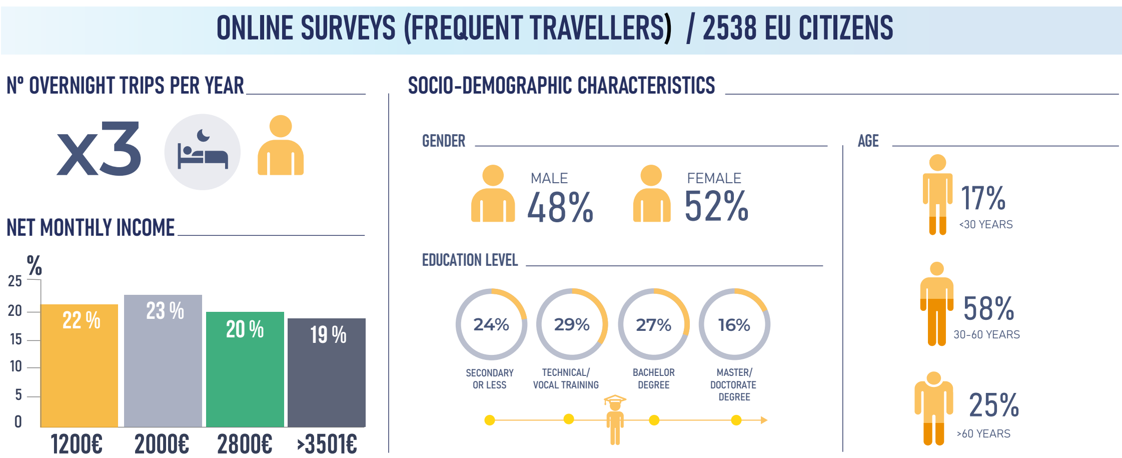


Figure 10.21. Socio-demographic profile of respondents.

Source: SOCLIMPACT Deliverable Report - D5.5. Report on market and non-market costs of Climate Change and benefits of climate actions for Europe.

Alternatives are defined by a set of attributes, each attribute taking one or more levels. Individuals' choices imply implicit trade-offs between the levels of the attributes in the different alternatives included in a choice set. In particular, he will pick the one providing the highest utility, which depends on the attribute levels of the alternatives. Socio-economic characteristics of the individual may influence this decision. The resulting choices are finally analyzed to estimate the contribution that each attribute and level add to the overall utility of individuals. Moreover, when the cost or price is included as an attribute, marginal utility estimates can easily be converted into willingness-to-pay (WTP) estimates for changes in the attribute levels and, by combining different attribute changes, welfare measures may be obtained (see **Figure 10.22**).

As a result of data analysis, a ranking of islands image was obtained, according to the opinion and the image that tourists have of each island under analysis. Besides, the percentage of tourists that would not visit any European island posed to climate change impacts was obtained, which alert on the potential decrease in tourism arrivals for these islands. Finally, the choice model allows to measure

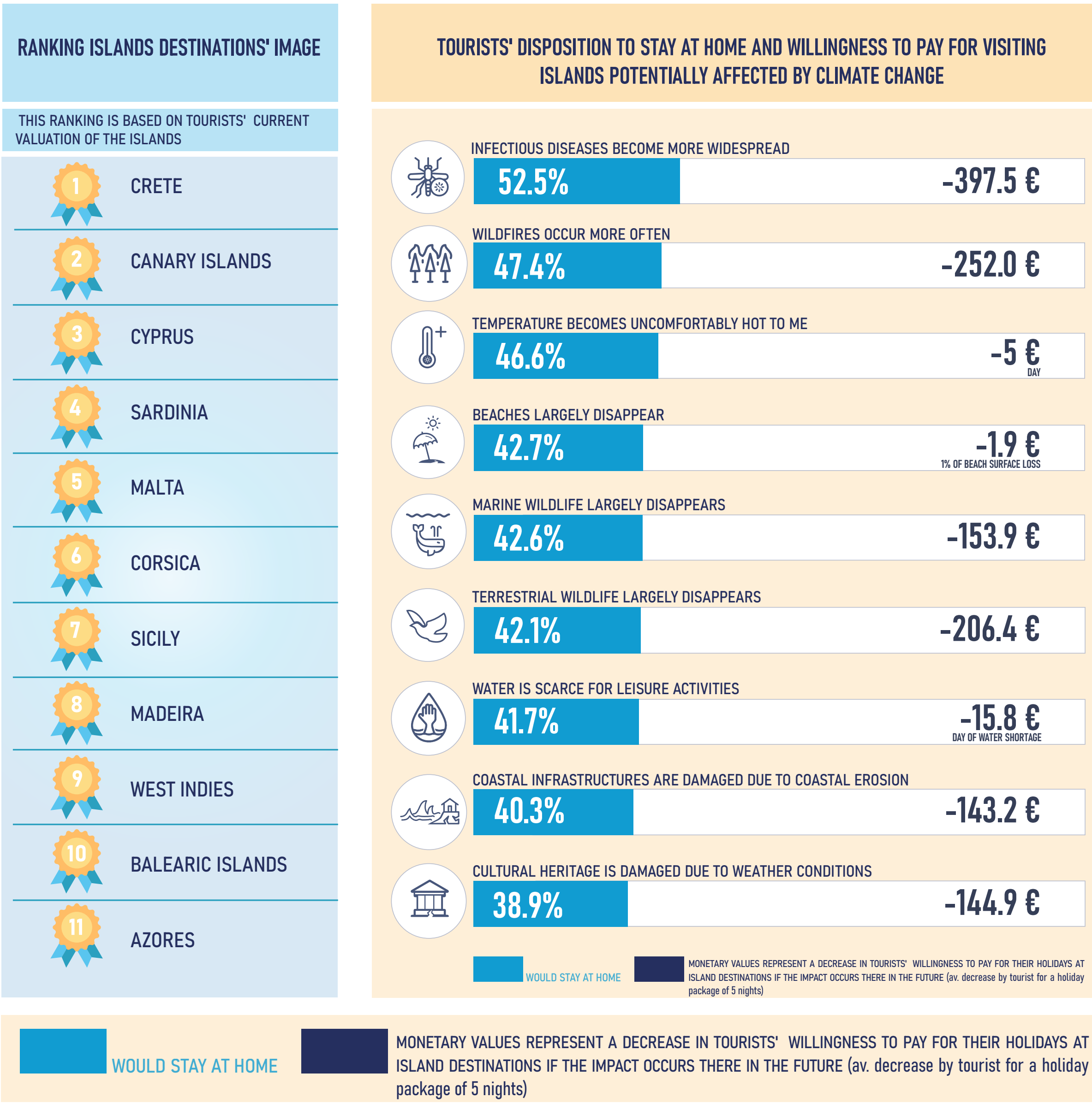


Figure 10.22. Tourists' preferences for islands destinations and behavioural response to climate change risks.

Source: SOCLIMPACT Deliverable Report - D5.5. Report on market and non-market costs of Climate Change and benefits of climate actions for Europe.

the changes in the tourists' willingness to pay for visiting these EU islands, which alert on how these impacts would affect tourism expenditure in the EU islands posed to climate change. The results are useful to evaluate the priorities in terms of risks management and responsiveness, from the tourism management perspective.

The impact of increased temperatures and heat waves on hotels' prices and revenues

In order to assess how the variation in temperature impacts on the tourism sector through changes in tourism demand, our research question was: "How do increasing temperatures (and heat waves) impact prices and, more in general, expenditure of tourists?" Arguably, when temperatures grow, tourists adjust their behaviour: they might switch destination, or they might stay longer or shorter depending on their attitudes and preferences. In turn, all these changes modify the market equilibrium, pushing tourism companies to adjust their prices to re-establish the equilibrium between demand and supply. The change in demand and the change in price determine the change in tourism expenditure, which is, from the destination's perspective, tourism revenue.

We monitored current weather conditions posted on several weather forecast providers and daily prices posted on Booking.com by hotels. We then estimated the link between daily temperature and daily price, controlling for all the other factors affecting prices. We finally applied these estimates to the increase in the number of days with excessive temperature projected for the future in two scenarios (RCP2.6 and RCP8.5) and in two time horizons (near future, about 2050 and distant future, about 2100).

Among the different indicators linked to thermal stress, we focus on two: the number of days in which the temperature is above the 98th percentile and the number of days in which the perceived temperature is above 35 °C. Although the impact for both indices was computed, in this document we only report the second one (named Humidex) because it is the most intuitive and because human thermal stress is more related to the absolute value of the temperature than its deviation from some pre-determined distribution. We assumed that thermal stress appears when the perceived temperature grows above 35 °C.

As thermal stress is delimited in the summer months, and this is when the great majority of tourists arrive in these islands, the whole analysis has been carried out in six months only: from May to October included. In other words, we assume that there is no thermal stress (and hence, no impact on tourism) in the rest of the year.

Initially, three islands were investigated: Corsica, Sardinia, and Sicily, given the massive amount of potential data. We focused the analysis in three specific areas, represented in the map below: the south-east area of Corsica (between Porto Vecchio and Boniface); the north-east area of Sardinia (Costa Smeralda) and the south-east area of Sicily (the coastal area of Catania and Siracusa provinces). Arguably, these are among the most important coastal tourism areas of these islands. Overall, 60 hotels (for a total of about 240,000 observations) were monitored in Corsica; 150 hotels (for a total of about 620,000 observations) were monitored in Sardinia; 129 hotels were monitored in Sicily (for a total of about 726,000 observations) over the period May 1, 2019 – October 31, 2019 (see **Figure 10.23**).

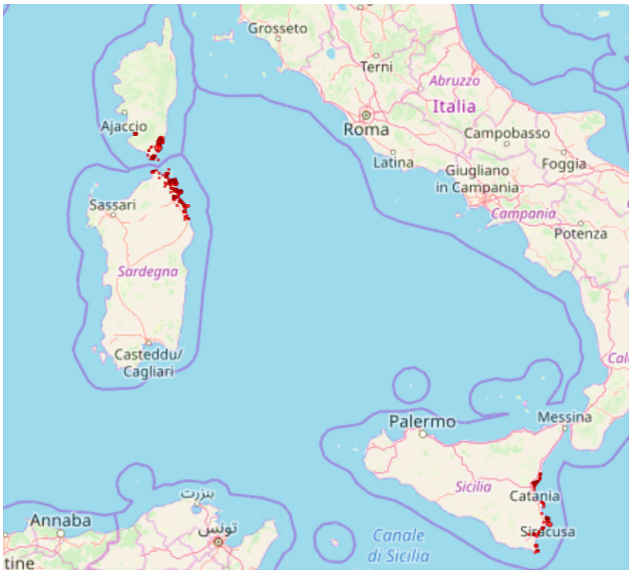


Figure 10.23. Map of the region.

Source: SOCLIMPACT Deliverable Report - D5.3. Data Mining from Big Data Analysis.

Nowadays, 27.23 % (column 1 of the table below) of "summer" days (days in the period between May 1 and October 31) have a Humidex higher than 35 °C in the area under investigation (Costa Smeralda).

In the future, this share (column 3) will increase to about 35-36 % in RCP2.6, to 37.59 % in RCP8.5 (near) and to 61.48 % in RCP8.5 (distant). Consequently, demand for holidays in Sardinia will increase, and the new equilibrium shows an increase in the average price posted by hotels in the destination (column 4) as well as an increase in overnight stays (column 5, this is estimated using the past correlation between average prices and occupancy rates in hotels, data provided by STR). The joint impact of price and demand will lead to an increase in hotels revenues (last column of the table) and, assuming that the change in revenues spreads to the other tourism products in a similar way, an increase in tourism revenues for the whole destination will be recorded. Hence, the estimation reported in the last column of the table below can be interpreted as the percentage increase in tourism revenues for the island (see **Table 10.5**).

Table 10.5. Estimation of increase in average price and revenues for Sardinia.

Actual share of days in which Humidex > 35 degrees	Future scenario considered	Days in the corresponding scenario in which Humidex > 35 degrees	Increase in the average price	Increase in the tourism overnight stays	Increase in tourism revenues
27.23%	RCP 2.6 near	35.78%	3.3%	0.7%	4.0%
	RCP 2.6 far	35.07%	3.0%	0.6%	3.7%
	RCP 8.5 near	37.59%	4.0%	0.8%	4.9%
	RCP 8.5 far	61.48%	13.3%	2.7%	16.3%

Source: SOCLIMPACT Deliverable Report - D5.3. Data Mining from Big Data Analysis.

According to these findings, the average increase in temperature, which is correlated to a growing thermal stress for tourists, brings an economic advantage to tourism destinations. This is only an apparent contradiction with previous findings. This study does not neglect the fact that if islands are too hot, tourists will choose to move to other (cooler) destinations, that theoretically exist. In this study, the underlying assumption is instead that growing temperatures are a global issue, thereby not modifying the relative position of a destination. Then, the increase in tourism (and tourism revenues) stem from the fact that, when the temperature is too hot, people would prefer to move to coastal areas (where the climatic conditions are more bearable) than staying inland or in cities. Future trends will also facilitate this pressure of tourism demand (think about the spreading of smart working activities where, in principle, the worker can relocate wherever he/she wants).

10.5.2. Aquaculture

The effects of increased sea surface temperatures on aquaculture production were calculated using a lethal temperature threshold by species, and considering the production share of the region. Four different future scenarios shown by IPCC estimations (RCP2.6 and RCP8.5, near and distant) were analysed, which correspond to four water temperature increases in the region (mean values), with respect to the reference period.

To do this, we assume three main species cultured in this region: Seabream, seabass and mussels, and a model of production function, calculating the monthly biomass production which depends on the monthly water temperature. Results are presented on a yearly basis (mean values). In order to facilitate the interpretation of the results, we present the value of production of the last year available, for which we calculate the new values under the different climate change scenarios.

As expected, the production levels (tons) will decrease for both, low and high emissions scenarios. In both cases, the average annual temperatures are projected in levels below 21°C, which are the thresholds of thermal stress for mussels, the most sensitive specie of the three analysed (see **Figure 10.24**).

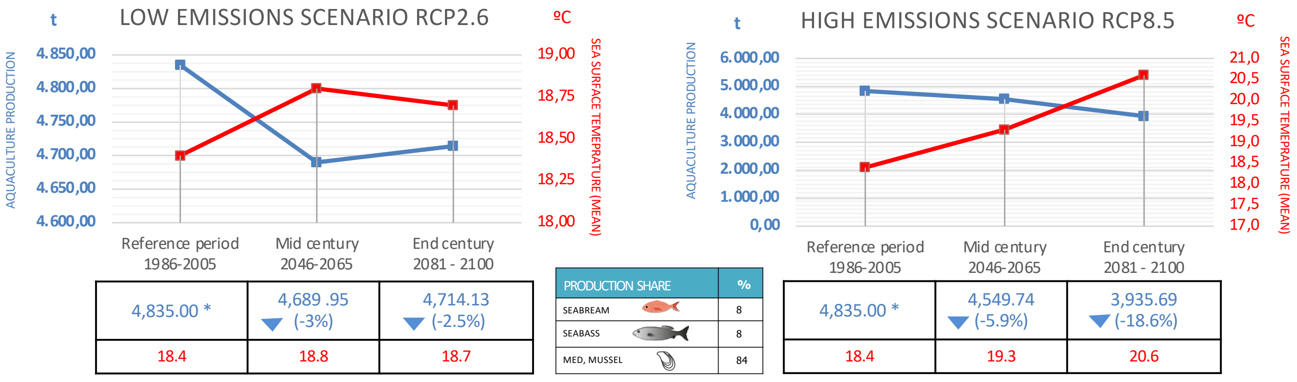


Figure 10.24. Estimations of changes in aquaculture production (tons), due to increased sea surface temperature.

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

10.5.3. Energy

Climate change may impose welfare reductions to the European islands' societies by affecting thermal comfort. Cooling Degree Days (CDD) are a measure of how much (in degrees), and for how long (in days), outdoor air temperature is higher than 21 °C. The CDD is used as a measure of the energy needed to cool buildings. The increase in CDD and the energy demand (GWh/year) for cooling are estimated for the islands under different scenarios of global climate change.

Under the high emissions scenario, it is expected that the CDD increase to 656 CDD[1]. Under this situation, the increase in cooling energy demand is expected to be 281 % (see **Figure 10.25**).

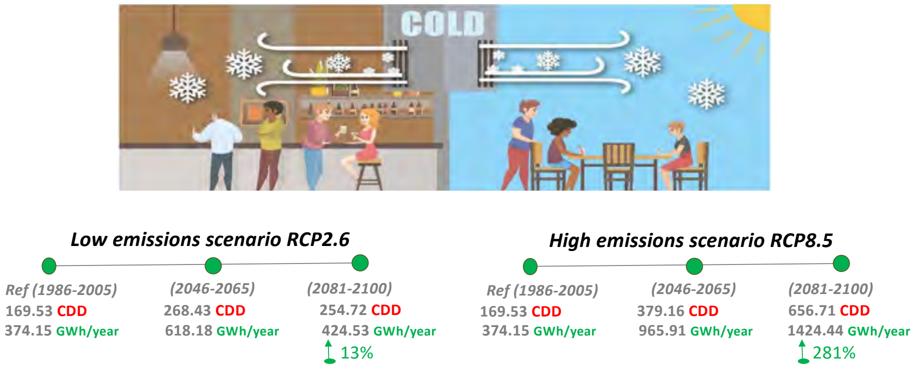


Figure 10.25. Estimations of increased energy demand for cooling in Sardinia under different scenarios of climate change until 2100.

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

The Standardized Precipitation Evapotranspiration Index (SPEI) is analysed as a representative indicator for increases in water demand for islands' residents, tourists and agriculture, while it also provides an indication on the available water stored in dams or underground resources. To estimate the increase of energy demand due to the increase in water demand, it was assumed that most of the islands will have to produce desalinated seawater (or groundwater) to meet further increases of demand. Thus, the estimation of the increase in energy demand (GWh/year**)** to produce more drinking water has been done based on the energy consumption required to desalinate seawater. Under the low emissions scenario (RCP2.6), there are not significant changes in the SPEI indicator, that will remain in its ¨normal¨ level, as it is nowadays. An increase of 113 % in desalination energy demand is expected under RCP8.5, a scenario with severe aridity for the island (see **Figure 10.26**).

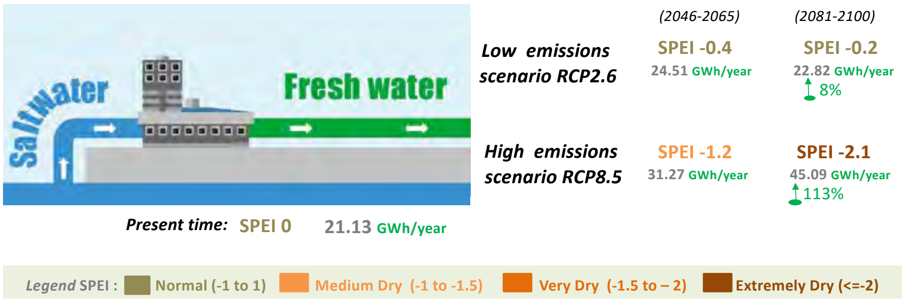


Figure 10.26. Estimations of increased energy demand for desalination in Sardinia under different scenarios of climate change until 2100.

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

[1] The indicator is computed by multiplying the number of days exceeding the threshold by the difference in temperatures.

10.5.4. Maritime Transport

For maritime transport, it has been estimated the impact of Sea Level Rise on ports' operability costs of the island. The costs have been calculated with reference to 1 meter; this is, the investment needed to increase the infrastructures' height by 1 meter. There is not necessarily a strict correspondence between the SLR and the required elevation of port infrastructures, which also depends on the coastal hydrodynamic and the shape of dikes of each port. By experts' recommendation, we have assumed that 1 meter increase in port height is required to cope with the SLR under RCP8.5 scenario of emissions. Extrapolation for other RCP scenarios is then conducted based on proportionality.

The starting point was the identification of the principal ports in each island (economic relevance). Second, the analysis of the different port areas (exterior, ramps, oil, etc.), and their uses. Third, the elevation costs were estimated per each area and port separately (considering 1 meter elevation). Thus, the costs of 1 meter elevation presented are the sum of all areas and ports analysed, and including the rest of the ports of the island (if applicable) based on proportionality. Estimations consider that all ports areas of the entire zone should be elevated at the same time. In other words, the economic values can be interpreted as the depreciation (amortization) costs of the investment needed to increase all porsts' infrastructures' in the island for 125 years time horizon. No discount rate has been applied.

As expected, the rising of sea levels will affect the sector, as new investment will be needed to keep ports' operability. Under the high emissions scenario, it is expected that these costs could increase by 1.9 million of euros per year until the end of the century (see **Figure 10.27**).

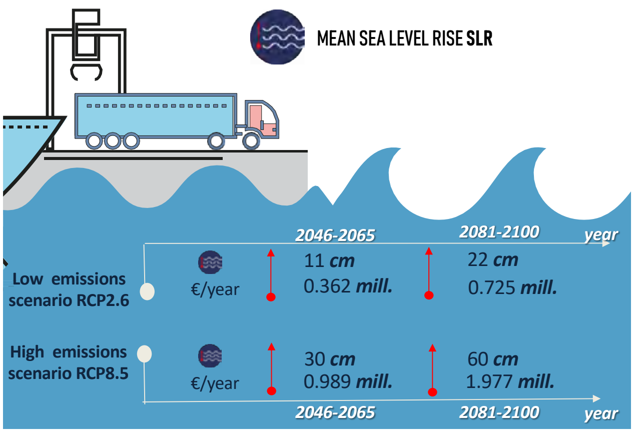


Figure 10.27. Increased costs for maintaining ports' operability in Sardinia under different scenarios of SLR caused by climate change until 2100.

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

10.6. Impacts on the Island's Socio-Economic System

In order to assess the socio-economic impacts of biophysical changes for the island of Sardinia, we have used the GEM-E3-ISL model, a single-region, multi-sectoral general equilibrium model based on the principles of neo-classical theory, and GINFORS, a macro-econometric model based on the principles of post-Keynesian theory.

Both models include 14 sectors of economic activity, with an emphasis on services and specifically on those composing the tourism industry. The GEM-E3-ISL model also includes endogenous representation of labor and capital markets as well as bilateral trade flows by sector.

Changes in the mean temperature, sea level and precipitation rates are expected to affect energy consumption, tourism flows and infrastructure developments. These impact-chains have been examined and quantified under two emission pathways: RCP2.6, which is compatible with a temperature increase well below 2°C by the end of the century, and RCP8.5, which is a high-emission scenario. The impact on these three factors was used as input in the economic models, which then assess the effects on GDP, consumption, investments, employment, etc.

In total, 18 scenarios have been quantified for Sardinia. The scenarios can be classified in the following categories:

1. Tourism scenarios: these scenarios examine the reduction in tourism revenues due to changes in human comfort as captured by the hum-index, the degradation of marine environment, the increased risk of forest fires and beach reduction. The aggregate tourism scenario (TOUR-SC6) assesses the economic impacts of a simultaneous change of all (the above-mentioned) factors.
2. Energy scenarios: the aggregate energy scenario (ENER-SC3) assessed the impacts on regional economic performance of increased total electricity demand driven by cooling and water desalination demand.
3. Infrastructure scenario: this scenario assesses the impact of port infrastructure damages (INFRA-MAR).
4. Aggregate scenarios: these scenarios examine the total impact of the previous-described changes in the economy.

The aim of the aggregate scenario is to examine the impacts on the economy of a simultaneous change in electricity consumption, tourism revenues and infrastructure damages. The scenario specifications for the two climatic variants are presented below (see **Table 10.6**).

The theoretical and structural differences of the two models mean that this study produces a reasonable range of impacts, given the uncertainty embodied in economic analysis and especially in the long-term.

In GEM-E3-ISL, the economy is in equilibrium at each point in time. Prices adjust to ensure that supply equals demand

Table 10.6. Aggregate scenario –inputs.

	Tourism revenues (% change from reference levels)	Electricity consumption (% change from reference levels)	Infrastructure damages (% of GDP)
RCP2.6 (2045-2060)	-11.17	4.50	-0.07
RCP2.6 (2080-2100)	-15.64	0.90	-0.09
RCP8.5 (2045-2060)	-39.17	10.90	-0.19
RCP8.5 (2080-2100)	-58.68	19.50	-0.25

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

(market clearing) and capital is fully used; however, the model allows for equilibrium unemployment as it takes into account labor market rigidities. The impacts are driven mainly by the supply side through changes in production costs which influence relative prices; hence, competitiveness and trigger substitution effects. The GEM-E3-ISL model assesses the impacts on the economy up to 2100.

The macro-econometric type of models, such as GINFORS, do not require that all markets are in equilibrium; idle capital and involuntary unemployment are some other features of this type of models where the results are driven mainly by adjustments in the demand side of the economy. The GINFORS assesses the impacts on the economy up to 2050.

With respect to GDP, the estimated reduction compared to the reference case is between 0.7% and 3% in the RCP2.6 in 2050 and between 2.5% and 8% in the RCP8.5. The cumulative reduction over the period 2040-2100 is estimated (by GEM-E3-ISL) to be equal to 1.1% in the RCP2.6 and 3.6% in the RCP8.5. The impacts on GDP are driven by the reduction in tourism related expenditures (see **Figure 10.28**).

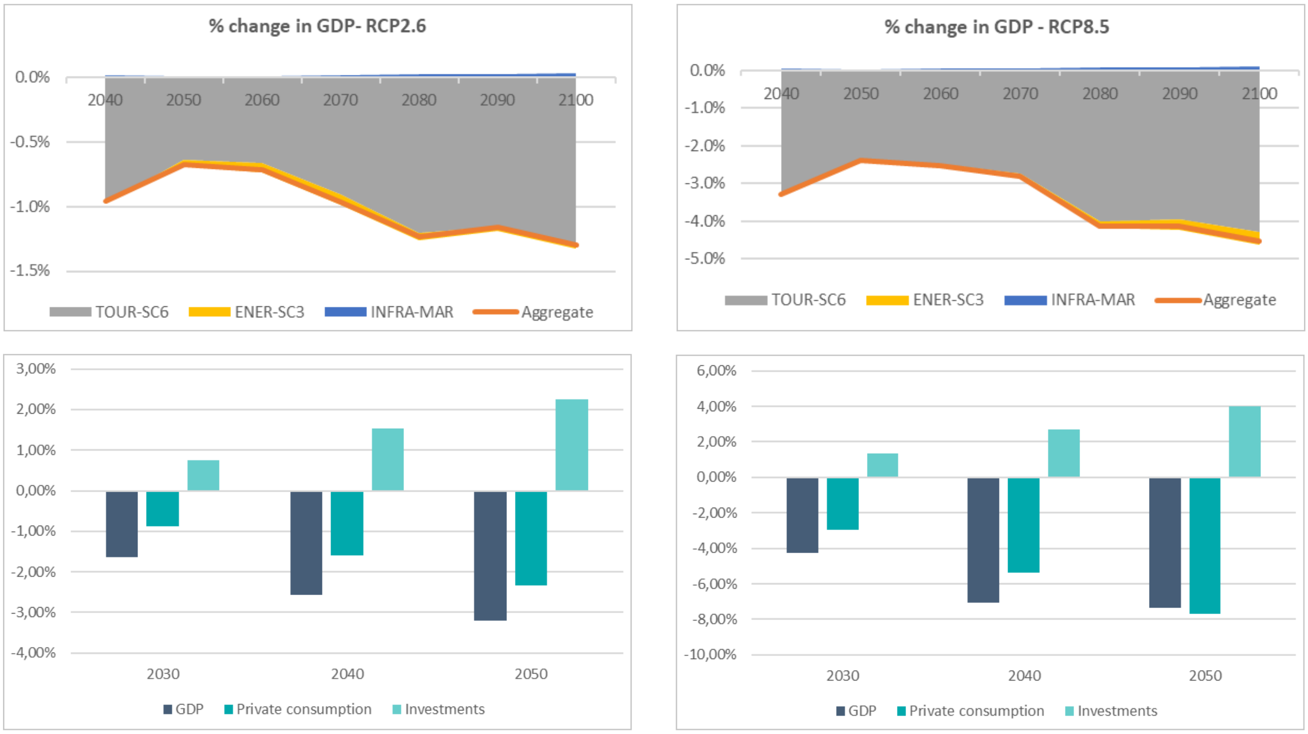


Figure 10.28. Percentage Change in GDP. GEM-E3-ISL results (above), GINFORS (below).

Source: own calculation.

With respect to sectoral impacts, both models show a significant decrease in the activity of tourism related sectors and an increase in the activity of the manufacturing industries, highlighting the opportunities for secondary sectors, in the context of economy's adaptation process. The increase of transport activity in the GEM-E3-ISL model is related to the increase in exports (see **Figure 10.29**).

Figure 10.29. *Production percentage change from reference.* GEM-E3-ISL results (above), GINFORS (below).
Source: own calculation.

Overall, employment falls in the economy and especially in tourism related sectors. In GEM-E3-ISL, increases in employment in non-tourism related activities are related to labor costs reductions (as wages fall) and a consequent substitution of capital with labor. Employment falls on average by 0.3% in the RCP2.6 and by 1.1% in the RCP8.5 (see **Figure 10.30**).

Figure 10.30. *Employment percentage change from reference.* GEM-E3-ISL results (above), GINFORS (below).
Source: own calculation.

10.7. Towards Climate Resiliency

According to the Regional Climate Change Adaptation Strategy (SRACC) 2019, the general commitments of the region are:

- Create a context of suitable conditions for adaptation, acting on the level of rules and process management;
- Create and support the ability to adapt, through knowledge and skills and their circulation, also providing the potential tools for the implementation of adaptation;
- Indicate effective paths of adaptation, integrating techniques, technologies and methodologies, giving priority to ecological, social and economic sustainability.

Furthermore, the general objectives contained in the regional strategy are:

1. Minimize the risks arising from climate change;
2. Protect the well-being, health and assets of the population;
3. Preserving the natural heritage;
4. Maintain or improve the resilience and adaptability of natural, social and economic systems;
5. Take advantage of any opportunities that might arise with the new weather conditions.

To date, spatial planning, urban planning and maritime spatial planning policies do not take into account the impacts of climate change.

Regional policies depend on national policies and national legislation to be followed. The main obstacles are slow procedures due to bureaucracy and funding constraints.

A limit is represented by the lower awareness of local authorities, the Sardinia region aims to increase the awareness of the problem to stimulate a dialogue between all stakeholders and actors in order to facilitate the promotion and implementation of effective actions.

Furthermore, there is a lack of reliable statistics and information related to exposure and vulnerability of the island to climate change. These are important components that worsen climate risks and respond to human interventions (more pressure). The island's adaptation focus should be, first, the development of reliable information systems for the periodic monitoring of these components.

10.7.1. Policy Recommendations

A stakeholders consultation process was carried out in the island, aiming to propose, analyse and rank alternative adaptation measures for the island. The profile of the individuals participating in these focal groups involved policy and decision-makers, practitioners, non-governmental and civil society organisations, science experts, private sector, business operators and sector regulators at island level.

The main aim of these meetings was:

1. Identify and present the characterized packages of adaptation and risk management options for the island.
2. Develop detailed integrated adaptation pathways in three timeframes: Short term (up to 2030), Mid-century (up to 2050) and End-century (up to 2100).
3. Evaluate and rank adaptation options for 4 blue economy sectors in the island (energy, maritime transport, aquaculture and tourism).

To this aim, stakeholders utilized five evaluation criteria to rank the proposed measures:

- Cost efficiency: Ability to efficiently address current or future climate hazards/risks in the most economical way.
- Environmental protection: Ability to protect the environment, now and in the future.
- Mitigation win-wins and trade-offs: Current ability to meet (win-win) or not (trade-off) the island / archipelagos mitigation objectives.
- Technical applicability: Current ability to technically implement the measure in the island.
- Social acceptability: Current social acceptability of the measure in the island.

Four scenarios of intervention were analysed, called Adaptation Policy Trajectories which are different visions of future policy adaptation choices:

- APT A Minimum Intervention - Low investment, low commitment to policy change.
- APT B Economic Capacity Expansion - High investment, low commitment to policy change.
- APT C Efficiency Enhancement - Medium investment, medium commitment to policy change.
- APT D System Restructuring - High investment, high commitment to policy change.

It was assumed that adapting to climate change may range from minimal to high cost, and from requiring a small or incremental change to a significant transformation from the *status quo*. However, not all APT scenarios were considered in all islands, especially when their stakeholders had a clear vision on the types of measures with greatest viability. Therefore, the final set of proposed adaptation measures are framed in the islands' socio-economic and political context, have a sectoral perspective, and respond to the islands' future scenarios of climate change. At the same time, the involvement of regional stakeholders in policy design allows them to engage in the effective implementation of climate actions on their island.

In Appendices from K to N, a brief explanation of each adaptation option can be found, classified by type or class: Vulnerability Reduction, Disaster Risk Reduction, Social-Ecological Resilience, and Local Knowledge. The latest group refers to very specific measures proposed by stakeholders in each island to ratify the needs.

10.7.1.1. Tourism

Overall, the adaptation pathways for the tourism sector in Sardinia are characterized by a significant homogeneity across adaptation objectives. The economic policy instruments are preferred options in the longer term than other measures such as financial incentives to retreat from high-risk areas. Likewise, drought and water conservation plans are preferred over coastal protection structures.

Under APT B and D scenarios, the region focuses on the development of economic policy instruments and the diversification of the activities and products. However, in Minimum Intervention scenario (APT A), investment in public awareness can be appropriate for mid and long-term.

The option related with water local sustainable fishing was excluded from all periods when an Efficiency Enhancement scenario (APT C) is considered, but was selected in a System Restructuring scenario (ATP D) in the long-term. The pathways developed seem to consider the growing evolution of the climate change risks and the urgency to respond to them with water restrictions, consumption cuts and grey-water recycling. Beach nourishment (or replenishment) was valued in the beginning of the century, while towards the end of the century, the region should invest in desalinization.

For Disaster Risk Reduction (DRR), and to manage long term risk, the decisions need to be sensible to the level of investment and reflects the climate change risk identified for the region. Drought and water conservation plans are a priority for the region throughout all scenarios. The risks related with fire were considered high in all time periods in Sardinia. The pathway clearly reflects the climate-risk context of the region.

Generically, to address DRR on tourism sector, it is necessary to allocate funds in the short-term for the immediate impacts, but then promote early recovery planning for the medium and long-term to develop climate change resilience in the region.

In Social-Ecological Resilience, groundwater management is not urgent for the sector. The region should, in the next decades, invest efforts in information systems to improve climate information reliability.

Options for the regulation of natural services in the tourism sector will benefit from the maintenance of the rivers/valleys functions, creating recreational areas with a positive impact on tourism attractiveness. Regulating and maintenance services are only defined within medium and low commitment to policy change. In this context, coastal restoration should only happen when coastal risks increase in the end of the century.

In medium investment and medium commitment to policy change scenario (APT C - Efficiency Enhancement), cultural services are relevant. In this case, the region considered to dedicate efforts to preserve and minimize the impacts on biodiversity and ecosystems, while also preserving the attractiveness of the region (see **Table 10.7**).

Table 10.7. Proposed adaptation options for tourism in Sardinia.

<table>
<tr><th rowspan="6">APT A – Pathway
—
Minimum Intervention
low investment, low commitment to policy change
—
This policy trajectory assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts</th><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td>Activity and product diversification</td><td colspan="2">Public awareness programmes</td></tr>
<tr><td colspan="3">Drought and water conservation plans</td></tr>
<tr><td colspan="3">Fire management plans</td></tr>
<tr><td>Post-disaster recovery funds</td><td colspan="2">Pre-disaster early recovery planning</td></tr>
<tr><td colspan="3">Monitoring, modelling and forecasting systems</td></tr>
<tr><th rowspan="7">APT B – Pathway
—
Economic Capacity Expansion
high investment, low commitment to policy change
—
This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy</th><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td colspan="3">Economic Policy Instruments (EPIs)</td></tr>
<tr><td>Public awareness programmes</td><td colspan="2">Activity and product diversification</td></tr>
<tr><td colspan="2">Beach nourishment</td><td>Desalination</td></tr>
<tr><td colspan="3">Drought and water conservation plans</td></tr>
<tr><td colspan="3">Monitoring, modelling and forecasting systems</td></tr>
<tr><td colspan="2">River rehabilitation and restoration</td><td>Dune restoration and rehabilitation</td></tr>
</table>

Table 10.7 (Cont.). Proposed adaptation options for tourism in Sardinia.

<table>
<tr><td rowspan="9">APT C – Pathway
—
Efficiency Enhancement
medium investment, medium commitment to policy change
—
This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system</td><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td colspan="3">Activity and product diversification</td></tr>
<tr><td colspan="2">Tourist awareness campaigns</td><td>Local circular economy</td></tr>
<tr><td colspan="3">Water restrictions, consumption cuts and grey-water recycling</td></tr>
<tr><td colspan="3">Drought and water conservation plans</td></tr>
<tr><td colspan="3">Mainstreaming Disaster Risk Management</td></tr>
<tr><td colspan="3">Monitoring, modelling and forecasting systems</td></tr>
<tr><td colspan="2">River rehabilitation and restoration</td><td>Dune restoration and rehabilitation</td></tr>
<tr><td colspan="2">Adaptive management of natural habitats</td><td>Ocean pools</td></tr>
<tr><td rowspan="7">APT D – Pathway
—
System Restructuring
high investment, high commitment to policy change
—
This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems</td><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td colspan="3">Economic Policy Instruments (EPIs)</td></tr>
<tr><td>Public awareness programmes</td><td colspan="2">Activity and product diversification</td></tr>
<tr><td colspan="2">Water restrictions, consumption cuts and grey-water recycling</td><td>Local sustainable fishing</td></tr>
<tr><td>Coastal protection structures</td><td colspan="2">Drought and water conservation plans</td></tr>
<tr><td>Post-disaster recovery funds</td><td colspan="2">Pre-disaster early recovery planning</td></tr>
<tr><td colspan="3">Monitoring, modelling and forecasting systems</td></tr>
</table>

Vulnerability Reduction · *Disaster Risk Reduction* · *Socio-Ecological Resilience* · *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

10.7.1.2. Maritime transport

The regional priority for all APTs is "Awareness campaigns for behavioural change" for the short term. For the medium and long terms, in all scenarios, the regional priority is "Social dialogue for training in the port sector" and the"Increase operational speed and flexibility in ports" underling the concerns with the foreseen sea level rise in these time frames.

Under the APT C, the regional priority was "Climate resilient economy and jobs" for all time frames, which underlines the importance to reduce imported goods from the exterior. Under the APT C and D, in all time frames, the measure "Restrict development and settlement in low-lying areas" was also considered a clear priority.

For Disaster Risk Reduction, "Climate proof ports and port activities" was consider a priority for the APT A for all time frames, for the APT B, C and D for the short and mid-term, and "consider expansion/retreat of ports in urban planning" for the long-term. This underlines the island dependence from the exterior and the importance of preventing the disruption of port activities due extreme weather events.

The establishement of an "Early Warning Systems (EWS) and climate change monitoring" was consider a clear priority for the medium and long terms. In Social-Ecological Resilience adaption objective, the measure "Marine life friendly coastal protection structures" was selected for the long term for the APTs A, B and D, showing the priority of "combined protection and wave energy infrastructures" on the short and mid-term, which indicates the potential contribution of wave energy for islands energy independence (see **Table 10.8**).

Table 10.8. Proposed adaptation options for maritime transport in Sardinia.

<table>
<tr><td rowspan="7">APT A – Pathway
—
Minimum Intervention
low investment, low commitment to policy change
—
This policy trajectory assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts</td><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td>Awareness campaigns for behavioural change</td><td colspan="2">Social dialogue for training in the port sector</td></tr>
<tr><td colspan="3">Climate proof ports and port activities</td></tr>
<tr><td colspan="3">Intelligent Transport Systems (ITS)</td></tr>
<tr><td>Post-disaster recovery funds</td><td colspan="2">Backup routes and infrastructures during extreme weather</td></tr>
<tr><td colspan="2">Combined protection and wave energy infrastructures</td><td>Marine life friendly coastal protection structures</td></tr>
<tr style="display:none"></tr>
<tr><td rowspan="8">APT B – Pathway
—
Economic Capacity Expansion
high investment, low commitment to policy change
—
This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy</td><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td colspan="2">Financial incentives to retreat from high-risk areas</td><td>Insurance mechanisms for ports</td></tr>
<tr><td>Awareness campaigns for behavioural change</td><td colspan="2">Social dialogue for training in the port sector</td></tr>
<tr><td colspan="3">Increase operational speed and flexibility in ports</td></tr>
<tr><td colspan="2">Climate proof ports and port activities</td><td>Consider expansion/retreat of ports in urban planning</td></tr>
<tr><td colspan="2">Combined protection and wave energy infrastructures</td><td>Marine life friendly coastal protection structures</td></tr>
<tr><td>Coastal protection structures</td><td colspan="2">Hybrid and full electric ship propulsion</td></tr>
<tr style="display:none"></tr>
<tr><td rowspan="10">APT C – Pathway
—
Efficiency Enhancement
medium investment, medium commitment to policy change
—
This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system</td><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td>Awareness campaigns for behavioural change</td><td colspan="2">Social dialogue for training in the port sector</td></tr>
<tr><td colspan="3">Climate resilient economy and jobs</td></tr>
<tr><td colspan="3">Restrict development and settlement in low-lying areas</td></tr>
<tr><td colspan="2">Climate proof ports and port activities</td><td>Consider expansion/retreat of ports in urban planning</td></tr>
<tr><td>Reinforcement of inspection, repair and maintenance of infrastructures</td><td colspan="2">Early Warning Systems (EWS) and climate change monitoring</td></tr>
<tr><td colspan="3">Combined protection and wave energy infrastructures</td></tr>
<tr><td colspan="2">Coastal protection structures</td><td>Hybrid and full electric ship propulsion</td></tr>
<tr><td colspan="3">Integrate ports in urban tissue</td></tr>
<tr style="display:none"></tr>
<tr><td rowspan="8">APT D – Pathway
—
System Restructuring
high investment, high commitment to policy change
—
This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems</td><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td colspan="3">Financial incentives to retreat from high-risk areas</td></tr>
<tr><td>Awareness campaigns for behavioural change</td><td colspan="2">Social dialogue for training in the port sector</td></tr>
<tr><td colspan="3">Restrict development and settlement in low-lying areas</td></tr>
<tr><td colspan="2">Climate proof ports and port activities</td><td>Consider expansion/retreat of ports in urban planning</td></tr>
<tr><td colspan="2">Backup routes and infrastructures during extreme weather</td><td>Post-disaster recovery funds</td></tr>
<tr><td colspan="2">Combined protection and wave energy infrastructures</td><td>Marine life friendly coastal protection structures</td></tr>
<tr style="display:none"></tr>
</table>

Vulnerability Reduction | *Disaster Risk Reduction* | *Socio-Ecological Resilience* | *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

10.7.1.3. Energy

The regional priority for the APT B, C and D is "Green jobs and businesses" for all time frames.

Under the APT C, the regional priority is "Small scale production and consumption (prosumers)" for the short and mid-term, and "Risk reporting platform" for the long-term.The measure "Energy storage systems" is considered a priority for all time frames for the APT C and APT D. This measure will allow Sardinia to decrease its dependency from fossil fuels, and thus, increasing its resilience to climate change except for APTD, where the mid-term "collection and storage of forest fuel loads" is selected.

In Social-Ecological Resilience adaptation objective, the region gives priority to "Energy efficiency in urban water management" for the short and medium term for APT A (Minimum Intervention), APT B (Economic Capacity Expansion), APT C (efficiency enhancement) and only for the short-term for APT D (System Restructuring), in contrast to "underground tubes and pipping in urban planning" which were selected for the long-term.

"Urban green corridors" was another measure ratified by local stakeholders, as they recognized the importance of reducing the air temperatures in the cities without increasing the consumption of energy for cooling, improving the quality of life in open spaces. Another clear priority proposed is to promote "Educational garden plots" in the short-term, which highlights the importance to reduce the food carbon footprint and food security in islands, followed by "heated pools with waste heat from power plants" for the mid and long-term (see **Table 10.9**).

Table 10.9. Proposed adaptation options for the energy sector in Sardinia.

Pathway	Short-term (up to 2030)	Mid-century (up to 2050)	End-of-century (up to 2100)
APT A – Pathway — **Minimum Intervention** low investment, low commitment to policy change — This policy trajectory assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts	Public information service on climate action		Green jobs and businesses
	Review building codes of the energy infrastructure		
	Study and develop energy grid connections		
	Energy recovery microgrids	Local recovery energy outage capacity	
	Energy efficiency in urban water management		Underground tubes and piping in urban planning
APT B – Pathway — **Economic Capacity Expansion** high investment, low commitment to policy change — This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy	Financial support for buildings with low energy needs		
	Green jobs and businesses		
	Demand Side Management (DSM) of Energy		
	Upgrade evaporative cooling systems	Review building codes of the energy infrastructure	
	Energy efficiency in urban water management		Underground tubes and piping in urban planning
	Biomass power from household waste	Urban green corridors	
APT C – Pathway — **Efficiency Enhancement** medium investment, medium commitment to policy change — This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system	Green jobs and businesses		
	Small scale production and consumption (prosumers)		Risk reporting platform
	Energy storage systems		
	Upgrade evaporative cooling systems	Review building codes of the energy infrastructure	
	Early Warning Systems (EWS)	Grid reliability	
	Energy efficiency in urban water management		Underground tubes and piping in urban planning
	Urban green corridors	Biomass power from household waste	
	Educational garden plots	Heated pools with waste heat from power plant	

Table 10.9 (Cont.). Proposed adaptation options for the energy sector in Sardinia.

APT D – Pathway	Short-term (up to 2030)	Mid-century (up to 2050)	End-of-century (up to 2100)
System Restructuring high investment, high commitment to policy change — This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems	Financial support for buildings with low energy needs		
	Green jobs and businesses		
	Energy storage systems	Collection and storage of forest fuel loads	Energy storage ystems
	Upgrade evaporative cooling systems		
	Energy recovery microgrids		
	Energy efficiency in urban water management	Underground tubes and piping in urban planning	

Vulnerability Reduction *Disaster Risk Reduction* *Socio-Ecological Resilience* *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

10.7.1.4. Aquaculture

"Climate proof aquaculture activities" was a measure considered a priority for all APTs in the short and mid-term, while "Risk-based zoning and site selection" was selected for the long term.

For Disaster Risk Reduction, the "Environmental monitoring and Early Warning Systems (EWS)" was consider a priority in all time frames for the scenario where the measure was available. In the scope of disaster response, the priority for the short term was the establishement of "Contingency for emergency management, early harvest and/or relocation".

Under the post disaster recovery, the region gave priority to the measure "Recovery Post-disaster plans" for the short and mid-term for APT A and in the short term for the APT D, while "Recovery-disaster funds" was considered as priority for the long term.

In Social-Ecological Resilience adaptation objective, the region gave priority to "Species selection" for all time frames in APT A, C and D. For APT B, just for the short-term and for the medium and long-term the measure "Feed production" was chosen as a priority.

Under cultural services, the regional priority is to promote "Create educational visits" at the short and mid-term for the APT C, in order to increase awareness on aquaculture advantages, and "Aquaculture cuisine" at medium and long terms to increase the local consumption (see **Table 10.10**).

Table 10.10. Proposed adaptation options for aquaculture in Sardinia.

APT A – Pathway	Short-term (up to 2030)	Mid-century (up to 2050)	End-of-century (up to 2100)
Minimum Intervention low investment, low commitment to policy change — This policy trajectory assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts	Awareness campaigns for behavioural change	Efficient feed management	
	Risk-based zoning and site selection	Climate proof aquaculture activities	Risk-based zoning and site selection
	Contingency for emergency management, early harvest and/or relocation	Mainstreaming Disaster Risk Management	
	Recovery Post-disaster plans		Recovery Post-disaster funds
	Species selection		
APT B – Pathway	**Short-term (up to 2030)**	**Mid-century (up to 2050)**	**End-of-century (up to 2100)**
Economic Capacity Expansion high investment, low commitment to policy change — This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy	Financial schemes, insurance and loans	Tax benefits and subsidies	
	Awareness campaigns for behavioural change		Efficient feed management
	Recirculation Aquaculture Systems (RAS)		
	Climate proof aquaculture activities		Risk-based zoning and site selection
	Species selection	Feed production	
	Best Management Practices		

Table 10.10 (Cont.). Proposed adaptation options for aquaculture in Sardinia.

<table>
<tr><td rowspan="10">APT C – Pathway
—
Efficiency Enhancement
medium investment, medium commitment to policy change
—
This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td>Awareness campaigns for behavioural change</td><td>Efficient feed management</td><td>Awareness campaigns for behavioural change</td></tr>
<tr><td colspan="3">Addressing consumer and environmental concerns at the local level</td></tr>
<tr><td colspan="3">Integrated multi-trophic aquaculture</td></tr>
<tr><td colspan="2">Climate proof aquaculture activities</td><td>Risk-based zoning and site selection</td></tr>
<tr><td colspan="3">Environmental monitoring Early Warning Systems (EWS)</td></tr>
<tr><td colspan="3">Species selection</td></tr>
<tr><td colspan="3">Best Management Practices</td></tr>
<tr><td colspan="2">Create educational visits</td><td>Promote aquaculture cuisine</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="8">APT D – Pathway
—
System Restructuring
high investment, high commitment to policy change
—
This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td>Financial schemes, insurance and loans</td><td colspan="2">Tax benefits nd subsidies</td></tr>
<tr><td colspan="2">Awareness campaigns for behavioural change</td><td>Efficient feed management</td></tr>
<tr><td colspan="3">Integrated multi-trophic aquaculture</td></tr>
<tr><td colspan="2">Climate proof aquaculture activities</td><td>Risk-based zoning and site selection</td></tr>
<tr><td>Recovery Post-disaster plans</td><td colspan="2">Recovery post-disaster funds</td></tr>
<tr><td colspan="2">Species selection</td><td>Feed production</td></tr>
</table>

Vulnerability Reduction | *Disaster Risk Reduction* | *Socio-Ecological Resilience* | *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

Chapter 11

Sicily (Italy)

SOCLIMPACT

This project has received funding from
the European Union's Horizon 2020 research
and innovation programme under
Grant Agreement No 776661

CONTENTS

Sicily at a Glance

Sicily, in the south of Italy, is the largest and one of the most densely populated islands in the Mediterranean Sea. Together with its surrounding islands, Sicily forms an autonomous region of Italy. The island is mostly mountainous with a seismic and volcanic activity quite intense. Here there is the Europe's highest active volcano, Mount Etna (3,350 meters). The only wide valley is the fertile Plain of Catania in the east. The climate is subtropical and Mediterranean. Underground water and springs are plentiful. The natural vegetation of Sicily has been greatly reduced by human influence, and forests occupy only 4% of the territory.

The Blue Economy Sectors

- **Aquaculture**

  Aquaculture in Sicily is mainly based on seabass and seabream production, with an average ratio of 54 to 46%. Small and variable quantity of other marine species are produced, such as sharpsnout seabream, red porgy, common dentex, amberjack, meagre or Mediterranean bluefin tuna. Commercial shellfish culture is limited to small mussel farms in the provinces of Palermo, Messina and Syracuse. The Regional Pilot Centre for Aquaculture of Assessorato Agricoltura e Foreste of the Sicilian Region coordinates research, development and pilot scale production in fresh water aquaculture. This sector is expected to grow rapidly in the next few years.

- **Maritime Transport**

  Palermo is considered one of the Italian strategic ports for the Motorways of the Sea system by the Ministry of Transport. The Sicilian ports in which today Ro-Ro cabotage services are operated for the combined road-sea are: Palermo, Termini Imerese, Catania and Trapani. Considering the port facilities, Sicily exceeds the national average. Due to its geographical conformation, the region has in fact a large number of ports, but the type and quality of services offered is inadequate in relation to the structure of the production system and the demand for passenger and freight transport.

- **Energy**

  Renewable sources are hydroelectric, photovoltaics, from biomass. No renewable sources: Power stations with steam turbines powered by poly-fuel. Semi-thick dense oils and natural gas are used, creating a mix that has led to a certain control of emissions in compliance with environmental legislation. In the Aeolian Islands, it has been developed a "Plan for recovery and increase of installed capacity end adaptation of auxiliary systems" including the installation of 10 new electro diesel production groups. The end uses concern the equivalent consumption of primary energy sources in the four census macro-sectors: Primary, Civil, Industry and Transportation.

- **Tourism**

  Sicily's sunny, dry climate, scenery, cuisine, history and architecture attract many tourists from mainland Italy and abroad. The tourist season peaks in the summer months, although people visit the island all year round. Tourism is one of the most important sectors for the island economy. In 2018, Sicily had 15.1 million presences, with an increase of 4.9% respect the 2017, and almost 5 million of arrivals (+4.8% in respect of 2017). The average stay is 3 nights with a bed occupancy rate of about 20%, then very low. The most popular time of the year is from May to September.

11.1. Current Climate and Risks

The climate in Sicily is Mediterranean on the coast as well as in the little islands and archipelagos of the region, with a mild and rainy winter season and warm and sunny summers. The mid-seasons are quite mutable. On the coastline, specially on the south-west, the influence of the winds coming from Africa makes the climate torrid. In the inland, prevainly mountainous, the climate is almost continental on the hills, with winters moderately cold and summers quite torrid, and colder on the mountains.

In general, the rainfall is quite poor, specially at low altitude and on the coast, where the landscape is semi-arid. Over the 1,000 meters of altitude, snowfall can be abundant and frequent. For example, on the Etna Volcano, often snows also in the summer due to the Atlantic currents which affect the climate especially between the end of July and the beginning of August (see **Figure 11.1**).

CURRENT CLIMATE-RELATED RISKS

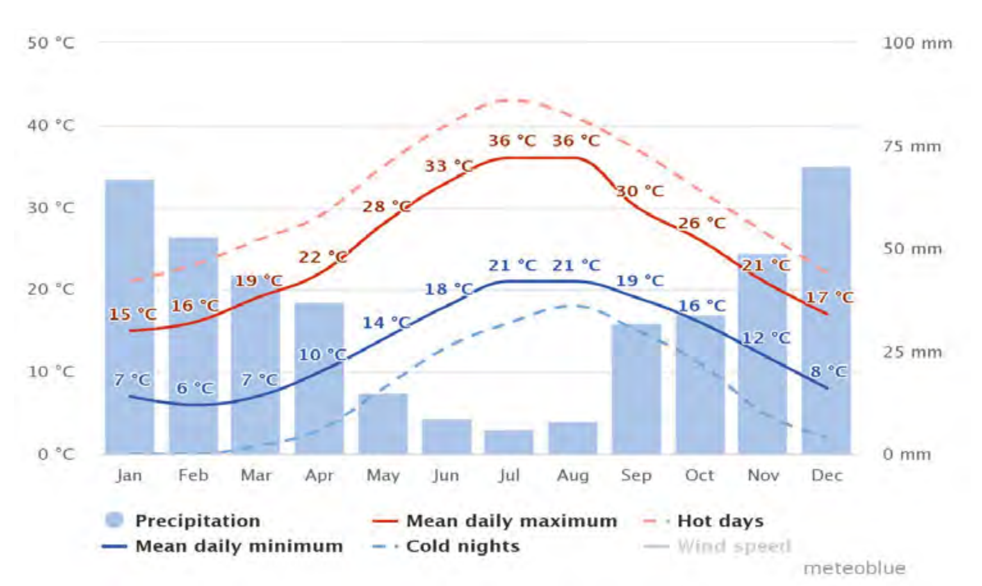
- Coastal flood High
- Wildfire High
- Water scarcity Medium
- Extreme heat Medium

SIGNIFICANT CLIMATE EVENTS

- Strong wind , February 2019
- Torrential rains and violent thunderstorms, November 2018
- Twister, August 2018, August 2013,
- Windstorm, November 2017, December 2009
- Windstorms, torrential rains and violent thunderstorms, October 2015.

CLIMATE CHARACTERISTICS (37.49°N 15.07°E, 7m asl)

Average temperature and precipitation



Wind speed

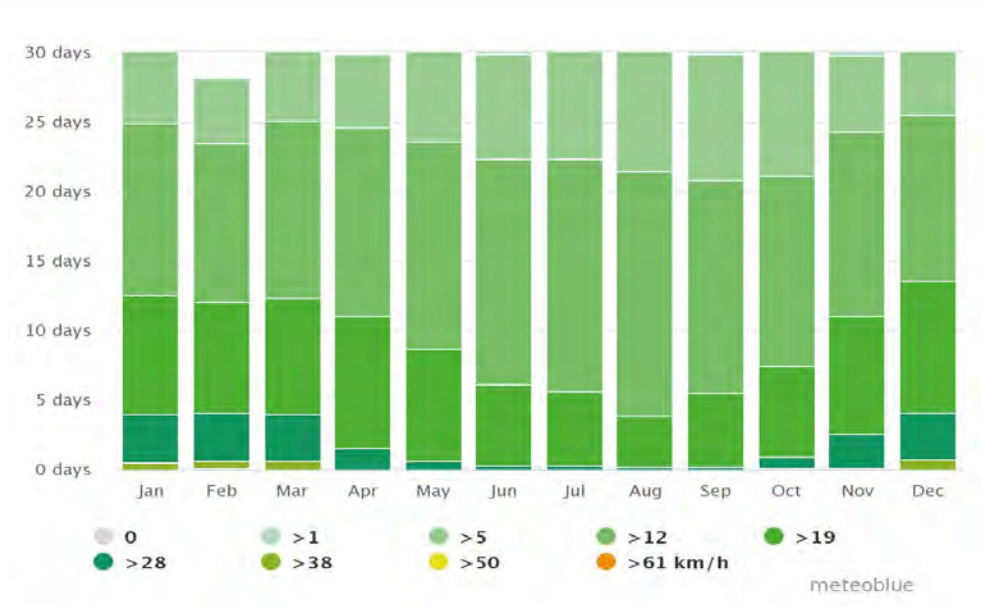
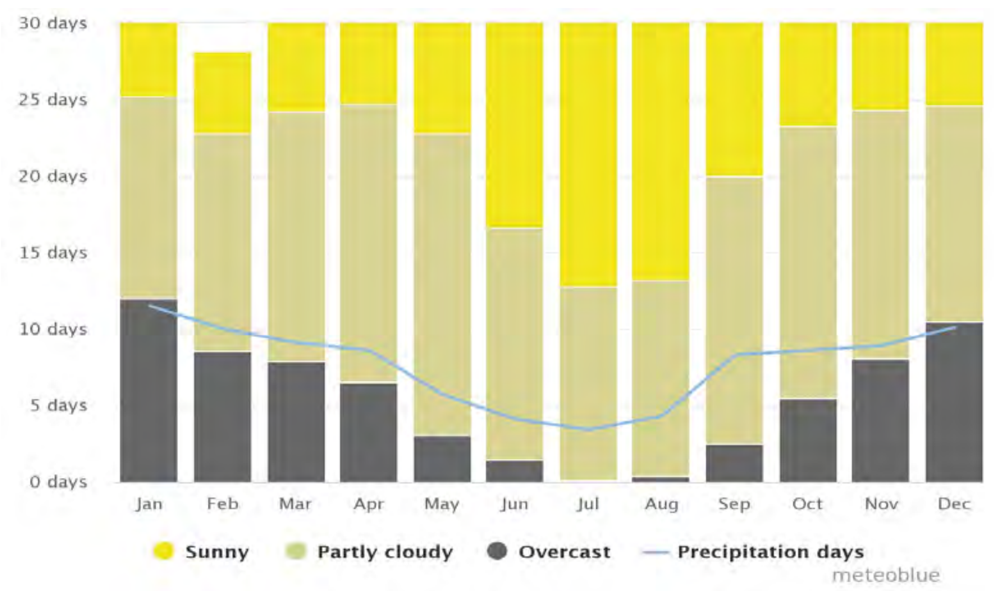


Figure 11.1. Climate factsheet

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System). **(Continued on the next page)**

Cloudy, sunny and precipitation



Wind rose

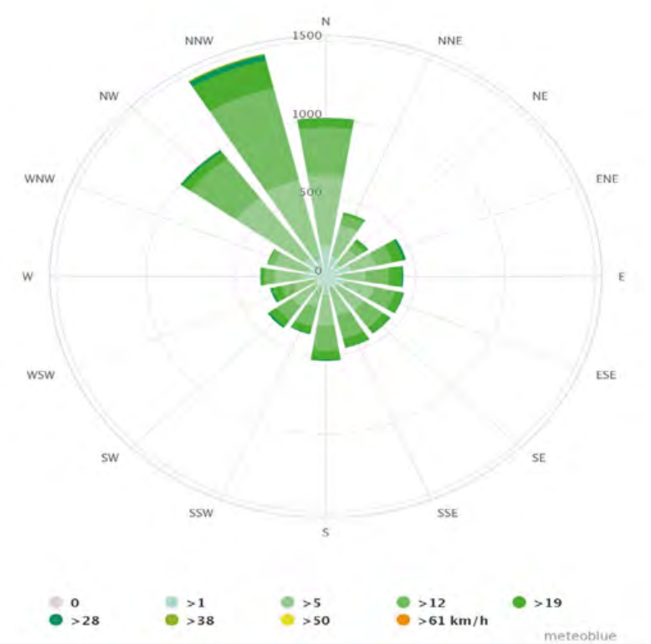


Figure 11.1 (Cont.). Climate factsheet

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System).

11.2. Macroeconomic Projections

In terms of GDP growth, Sicily registers a 1.3% yearly rate throughout the 2015-2100 period and a 1.1% rate in the 2015-2050 period. The main driver of growth during the entire period is investments, particularly in the short term, and a sustained private consumption throughout the period (Table 11.1).

As seen in Figure 11.2, the economy of Sicily is projected to become more sustainable, as the trade deficit gradually diminishes and the contribution of investments to GDP increases. The above imply a reduction of private and public consumption when expressed as a share of GDP. In particular, the share of public consumption in GDP, which was the highest among all islands in 2015, drops to levels similar to those of the rest of the islands (see **Table 11.1** and **Figure 11.2**).

Table 11.1. Sicily GDP and GDP components yearly growth rates in 2020-2100.

	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
GDP	1.3%	0.8%	0.5%	0.9%	0.9%	1.6%	1.6%	1.6%	1.5%	1.3%
Private consumption	1.7%	0.3%	-0.4%	0.2%	0.6%	1.3%	1.4%	1.4%	1.2%	1.1%
Public consumption	1.0%	0.4%	0.1%	0.6%	0.6%	1.2%	1.2%	1.3%	1.2%	0.8%
Investments	1.2%	2.7%	2.4%	2.9%	1.1%	1.9%	1.8%	1.7%	1.6%	1.3%
Trade	2.1%	0.0%	-1.4%	-0.2%	-0.7%	-0.1%	0.2%	0.4%	-0.2%	-1.8%

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

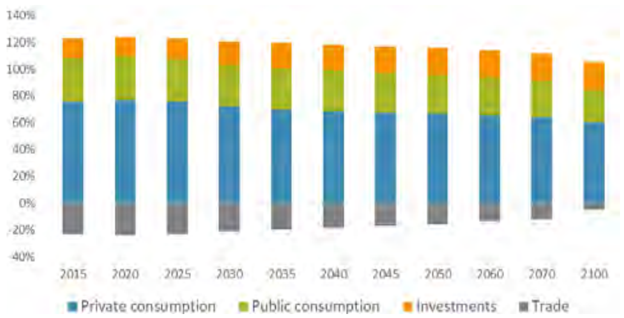


Figure 11.2. Macroeconomic components as a% share of GDP for Sicily in 2015-2100.

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

11.2.1. Sectoral Projections

The economy of Sicily remains a service-led economy throughout the 2015-2100 period. However, a transition from non-market towards market services is projected. Construction registers an increasing share in total value added, following the trajectory of investments. The share of blue economy sectors in total value-added falls slightly in the 2015-2100 period, as tourism falls slightly below 10% of GDP (see **Figure 11.3** and **Table 11.2**).

11.2.2. Employment

Sicily registers high unemployment levels, particularly among young people, which poses a challenge for future economic

Table 11.2. Sectoral contribution as a% share of total gross value added for Sicily in 2015-2100.

GVA% shares	2015	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
Agriculture	4.2%	4.0%	4.0%	4.0%	3.9%	3.9%	3.8%	3.7%	3.6%	3.5%	3.6%
Fishery	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.2%	0.2%	0.2%	0.2%
Manufacturing	4.1%	3.7%	3.5%	3.5%	3.4%	3.2%	2.9%	2.6%	2.2%	2.0%	1.8%
Consumer goods	1.3%	1.3%	1.3%	1.3%	1.3%	1.4%	1.4%	1.5%	1.8%	2.0%	2.2%
Electricity	1.3%	1.2%	1.2%	1.2%	1.2%	1.1%	1.1%	1.0%	0.9%	0.8%	0.8%
Water	1.4%	1.4%	1.4%	1.3%	1.3%	1.3%	1.2%	1.2%	1.1%	1.1%	1.0%
Construction	4.9%	5.1%	5.6%	6.1%	6.7%	6.9%	7.3%	7.7%	8.5%	9.1%	10.8%
Water transport	0.7%	0.7%	0.6%	0.6%	0.6%	0.6%	0.5%	0.5%	0.4%	0.3%	0.2%
Other transport	4.5%	4.4%	4.4%	4.4%	4.4%	4.4%	4.3%	4.2%	4.1%	4.0%	3.9%
Accommodation and food services	2.9%	3.0%	3.0%	3.1%	3.1%	3.1%	3.2%	3.3%	3.4%	3.4%	3.6%
Travel agency and related activities	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Recreational services	4.8%	4.8%	4.8%	4.7%	4.6%	4.5%	4.5%	4.5%	4.4%	4.3%	3.9%
Other market services	37.%	38.%	38.%	38.%	39.%	40.%	40.%	41.%	43.%	44.%	46.0%
Non-market services	32.%	31.%	31.%	30.%	30.%	29.%	28.%	27.%	26.%	25.%	21.9%

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

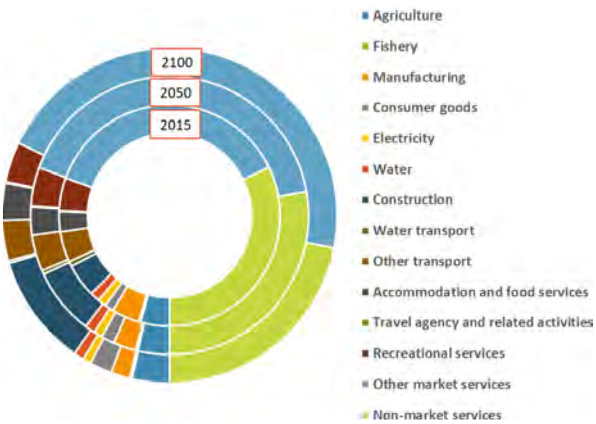


Figure 11.3. Sectoral value added as a% share to total GVA for Sicily in 2015, 2050 and 2100.

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

policies. Our reference projections assume a declining unemployment rate that falls by 13% in the 2015-2100 period (see **Table 11.3** and **Figure 11.4**). This positive evolution, However, is not the result of economic transformation and job creation, but rather the effect of the declining population. The only sector that shows higher employment numbers is construction. The next Figure describes the share of each sector in total employment, indicating that almost half of the Sicilian jobs are in the market services, while almost 10% of total employment is related to tourism.

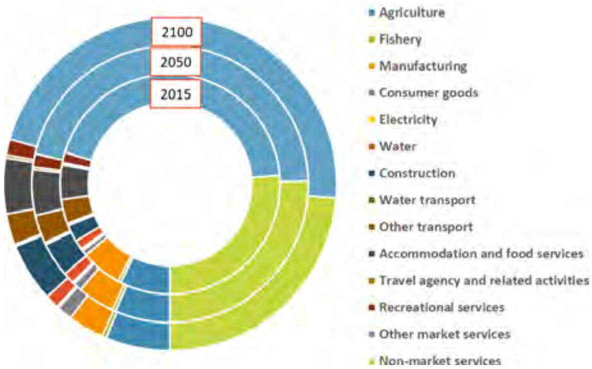


Figure 11.4. Sectoral employment as a% share of total for Sicily in 2015, 2050, 2100.

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

Table 11.3. Unemployment rate in Sicily in 2015-2100.

	2015	2020	2025	2030	2035	2040	2045	2050	2060	2070	2100
Unemployment rate	21.4%	20.4%	18.3%	16.2%	12.3%	11.0%	9.4%	8.5%	8.4%	8.2%	8.2%

Source: SOCLIMPACT Deliverable Report - D6.2. Macroeconomic outlook of the islands' economic systems and pre-testing simulations.

11.3. Climate Change Outlook

Climate hazards indicators represent the entry point to understand the climate change exposure of the blue economy sectors. The indicators have been computed for two scenarios, RCP2.6 (low emission scenario) and RCP8.5 (high emission scenario) and for different horizon times namely: a reference period (1965-2005), mid-century (2046-2065) and end of century (2081-2100). Main source of climate projections (future climate) for the Sicily is MED-CORDEX ensemble (regional scale of the Mediterranean area) and CMIP5 ensemble (global scale) even if other model sources were applied when required, depending of available scales. Results are presented in form of maps, tables or graphs and only when the information shows an interesting outcome.

11.3.1. Tourism

11.3.1.1. Seagrass evolution

Posidonia Oceanica is a foundation species in Mediterranean waters. Foundation species have a large contribution towards creating and maintaining habitats that support other species. First, they are numerically abundant and account for most of the biomass in an ecosystem. Second, they are at or near the base of the directional interaction networks that characterize ecosystems. Third, their abundant connections to other species in an ecological network mostly reflect non-trophic or mutualistic interactions, including providing structural support for other species, significantly altering ecosystem properties to [dis]favor other species, altering metabolic rates of associated species, and modulating fluxes of energy and nutrient flow through the system.

Seagrasses are the main habitat for coastal marine ecosystems. They provide different services like sediment retention (and thus, clearer waters), coastal protection (in front of marine storms), shelter for marine organisms, etc. Therefore, the state of seagrasses is a convenient proxy for the state of coastal environment. One species is located in the coasts of Sicily: Posidonia. The results of RCP8.5 projections indicate a loss of 28.3% at end of century (see **Figure 11.5**).

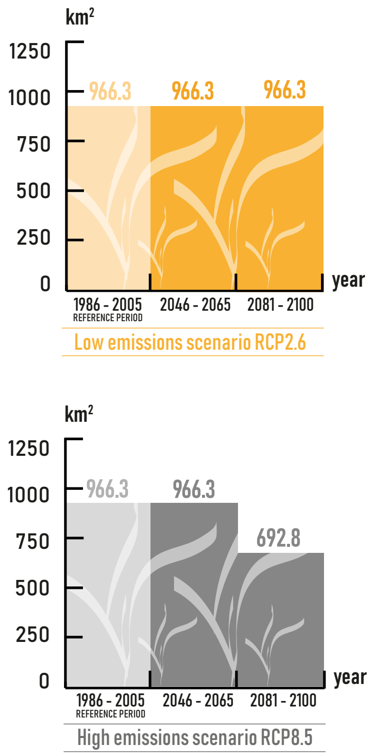


Figure 11.5. Projection of seagrass coverage.

Source: SOCLIMPACT project deliverable [D4.4e - Report] on estimated seagrass density.

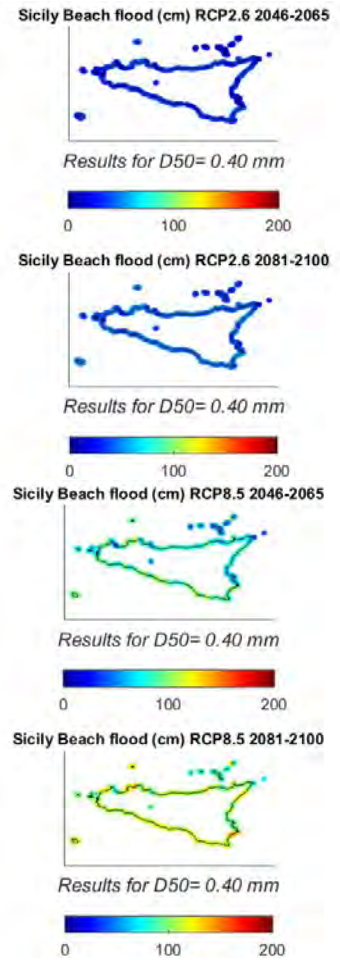


Figure 11.6. Projected extreme flood level (in the vertical, in cm) at beach locations with respect to the present (1986-2005) mean sea level values averaged for the islands under scenario RCP2.6 (left) and RCP8.5 (right). Own elaboration based on global and regional simulations.

Source: SOCLIMPACT Deliverable [Report - D4.4d]. Report on the evolution of beaches.

11.3.1.2. Beach flooding and related losses

One of the consequences of an increase in the mean sea level will be the flooding of coastal areas. This includes sand beaches, which are the main asset for tourism activities in most of the European islands. Therefore, estimating the potential risk of beach loss due to climate change is of paramount importance for the economy of those islands.

The 95th percentile of the flood level averaged was selected as an indicator of interest. The values are presented as anomalies with respect to the present mean sea level at beach location (i.e. including the median contribution of runup). An increase is expected being larger at the end of the century under scenario RCP8.5 (see **Figure 11.6**).

Under mean conditions, we find that, at end of century, the total beach surface loss range from ~34 % under scenario RCP2.6 to ~61 % under scenario RCP8.5 (see **Figure 11.7**).

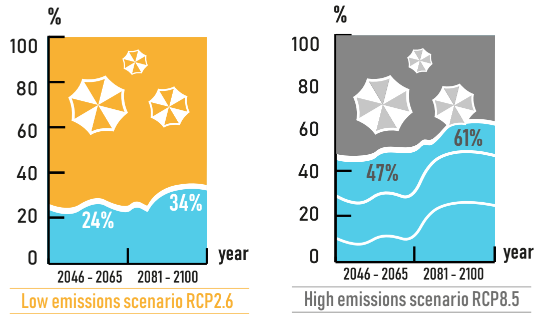


Figure 11.7. Beach reduction % (scaling approximation).

Source: SOCLIMPACT project deliverable [D4.4d - Report] on the evolution of beaches.

11.3.1.3. Fire Weather Index (FWI)

The FWI system provides numerical non-dimensional ratings of relative fire potential for a generalized fuel type (mature pine stands) based solely on weather observations. FWI is part of the Canadian Forest Fire Danger Rating System established in Canada since 1971 (van Wagner, 1987). Furthermore, since 2007, FWI has been adopted at the EU level and used in a harmonized way throughout Europe by the European Forest Fire Information System (EFFIS) of the Copernicus Emergency Management Service (since 2015).

It is selected for exploring the mechanisms of fire danger change for the islands of interest, as it has been proved to adequately perform for several locations, including the Mediterranean basin. The index was calculated for the fire season (defined from May to October) over the Mediterranean for all models, scenarios and periods.

For Sicily, N = 195 grid cells were retained from the models domain. In the following figure, the ensemble mean and the uncertainty are presented for all periods and RPCs. While most of the areas exhibit very low, low and medium fire danger in the present climate, and under RCP2.6 for the near and the distant future as well, it seems that under RCP8.5, more areas exhibit medium danger at mid-century, while towards the end of the century a major part of the island will be under medium and high fire danger. The overall increase of the risk score for the island exceeds 30% (see **Figure 11.8**).

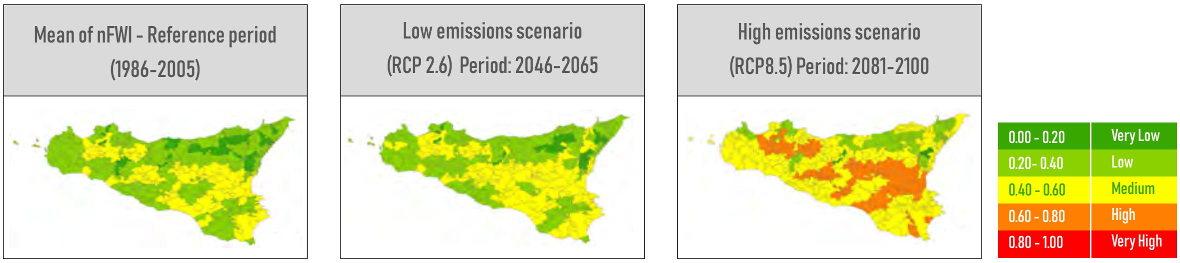
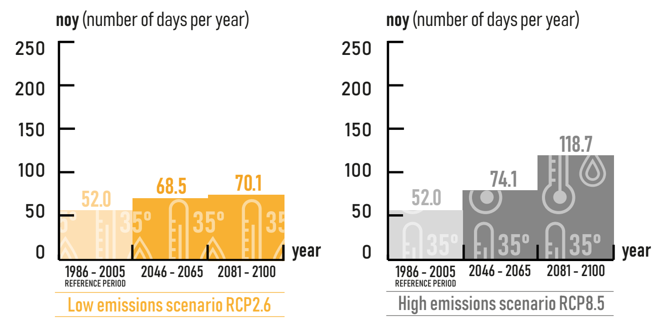


Figure 11.8. Fire Weather Index (EURO-CORDEX) with the color associated to the nivel of risk.
Source: SOCLIMPACT project deliverable D4.4c - Report on potential fire behaviour and exposure.

11.3.1.4. Humidex

For the assessment of climate hazard on heat related impacts of climate change on human health, the humidity index (Humidex) (Masterton and Richardson, 1979) has been used. Humidex value is an equivalent temperature, which express the temperature perceived by people (the one that the human body would feel), given the actual air temperature and relative humidity. As a more representative indicator for the assessment of inhabitants' and tourists' hazard on heat related climate change impacts, the number of days with Humidex greater than 35 °C was selected. From the above classification, a day with Humidex above 35 °C describes conditions from discomfort to imminent danger for humans.

For Sicily, N = 195 grid cells were retained from the models domain. In the following figure, the ensemble mean and the uncertainty are presented for all periods and RPCs. From less than 2 months in the present climate and quite above 2 months in the mid-century for both scenarios, Sicily will have almost 4 months with discomfort conditions by the end of the century under RCP8.5 (see **Figure 11.9**).



HUMIDITY INDEX-DISCOMFORT LEVEL	
<29°C	comfortable
30-34°C	some discomfort
35-39°C	discomfort; avoid intense exertion
40-45°C	great discomfort; avoid exertion
46-53°C	significant danger; avoid any activity
>54°C	imminent danger; heart stroke.

Figure 11.9. Number of days per year with Humidex > 35° C (Euro-CORDEX).
Source: SOCLIMPACT project deliverable D4.3. Atlases of newly developed indexes and indicator.

11.3.1.5. Length of the window of opportunity for vector-borne diseases

Vector Suitability Index for Aedes Albopictus (Asian Tiger Mosquito)

Climate change can influence the transmission of vector-borne diseases (VBDs) through altering the habitat suitability of insect vectors. This is mainly controlled by increases of ambient air temperature and changes in the hydrological cycle. We explore if potential changes to meteorological conditions can affect the distribution of the Asian tiger mosquito (Aedes albopictus). Asian tiger mosquito is native to the tropical and subtropical areas of Southeast Asia; however, in the past few decades, this species has spread to many countries through the international transport of goods and increased travel (Scholte and Schaffner, 2007). It is of great epidemiological importance since it can transmit viral pathogens and infectious agents that cause chikungunya, dengue fever, yellow fever and various encephalitides (Proestos *et al.,* 2015).

The multi-criteria decision support vector distribution model of Proestos *et al.* (2015) has been employed to estimate the regional habitat suitability maps. This is based on extending previous work on the environmental/climatic factors affecting the life cycle of the Asian tiger mosquito (Waldock *et al.*, 2013; Proestos *et al.*, 2015). The mosquito habitat suitability model combines seven meteorological indices based on field observations, extensive literature review and expert knowledge. The projection for the island indicates that the current situation will not be worsened. However, actual suitability index should be taken into account in climate policy design (see **Figure 11.10**).

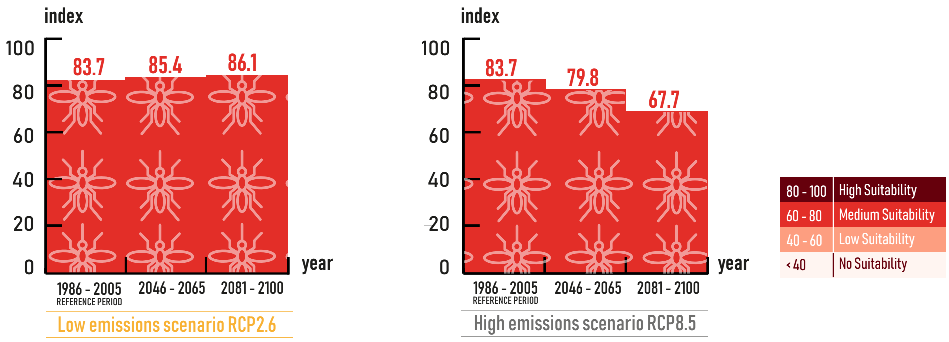


Figure 11.10. Habitat Suitability Index (HSI). [80-100: High Suitability; 60-80: Medium Suitability; 40-60: Low Suitability; <40 No Suitability]
Source: SOCLIMPACT project deliverable D4.3. Atlases of newly developed indexes and indicator.

11.3.2. Aquaculture

Temperature changes in seawater trigger physical impacts, such as increased harmful algal blooms, decreased oxygen level, increase in diseases and parasites, changes in ranges of suitable species, increased growth rate, increased food conversion ratio and more extended growing season. Furthermore, all these impacts lead to socio-economic implications among them: changes in production levels and an increase in fouling and pests. The objective of the current analysis is to identify and quantify the variations (future climate scenarios with respect to present climate) in the number and in the duration of events characterized by a Sea Surface Temperature (SST) exceeding a given threshold. The SST thresholds have been identified according to the farming and feeding necessities of several marine species, particularly relevant for the aquaculture sector in the Mediterranean Sea (MS) (see **Figure 11.11**).

More information can be found in the next section dedicated to risk assessment.

11.3.3. Energy

11.3.3.1. Standardized Precipitation Evaporation Index (SPEI)

As expected from the definition of SPEI, for our historical reference period, normal conditions are simulated for all islands. On average, simulations under pathway RCP2.6 indicate small changes in the SPEI values, and for most islands, near-normal conditions are expected throughout the 21st century as a result of the smaller changes in the precipitation regimes, combined with mild increases in near-surface temperature. Under the high emission RCP8.5 pathway all European Islands are expected to face much drier conditions. The signal becomes stronger towards the end of the 21st century (see **Figure 11.12**).

	Longest event (days) >20 degrees Mussels & clams	Longest event (days) >24 degrees Sea bream/Tuna	Longest event (days) >25 degrees Sea bass
Historic (1986-2005)	150 days	66.5 days	50 days
RCP 8.5 - mid century	172 days	93 days	73.5 days
RCP 8.5 - end century (2081-2100)	182 days	117.5 days	98.5 days

Species	Threshold (°C)
European seabass, Dicentrarchus labrax	25
Gilthead seabream, Sparus aurata	24
Amberjack, Seriola dumerili	23
Atlantic Bluefin tuna, Thunnus thynnus	23
Japanese clam, Ruditapes decussatus	21
Blue mussel, Mytilus edulis	21
Manila clam, Rudtape philippinarum	20
Mediterranean mussel, Mytilus galloprovinciales	20

Figure 11.11. Fish thermal threshold.

Source: SOCLIMPACT Deliverable Report - D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

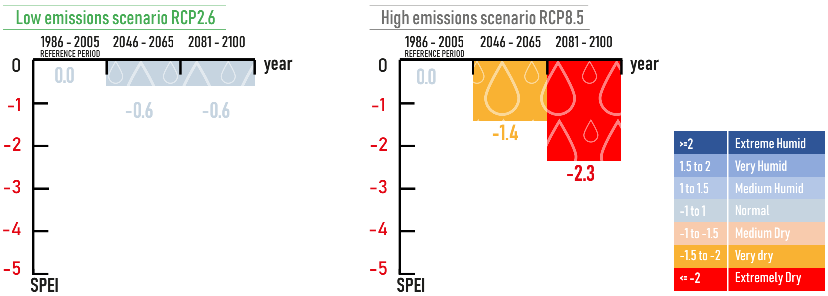


Figure 11.12. Ensemble mean, maximum and minimum values of the Standardized Precipitation Evaporation Index (SPEI) averaged over each SOCLIMPACT island and for each sub-period of analysis (EURO-CORDEX).

Source: SOCLIMPACT project deliverable D4.3. Atlases of newly developed indexes and indicator.

11.3.3.2. Percentage of days when T > 98th percentile - T98p

The T98p is defined as the percentage of time where the mean daily temperature T is above the 98th percentile of mean daily temperature calculated for the reference period 1986-2005. For Sicily, N = 195 grid cells were retained from the models domain. In the following figure, the ensemble mean and the uncertainty are presented for all periods and RCPs. It is found that T98p is about 5% during RCP2.6 towards mid-century and slightly decreases at the end of the century, while for RCP8.5 almost one fifth of the year will exhibit temperatures above the 98th percentile. The coastal grid cells are more affected by the temperatures increase compared to the inland grid cells (see **Figure 11.13**).

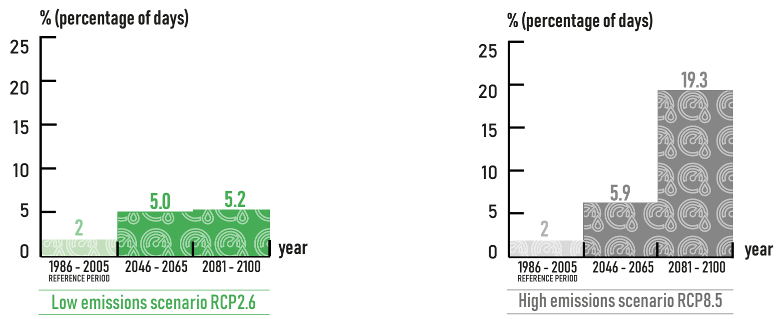


Figure 11.13. *Percentage of days when T > 98th percentile (EURO-CORDEX).*

Source: SOCLIMPACT project deliverable D4.3. Atlases of newly developed indexes and indicator.

11.3.3.3. Cooling Degree Days (CDD)

The Cooling Degree Days (CDD) index gives the number of degrees and the number of days that the outside air temperature at a specific location is higher than a specified base temperature, providing the severity of the heat in a specific time period taking into consideration outdoor temperature and average room (see **Figure 11.14**).

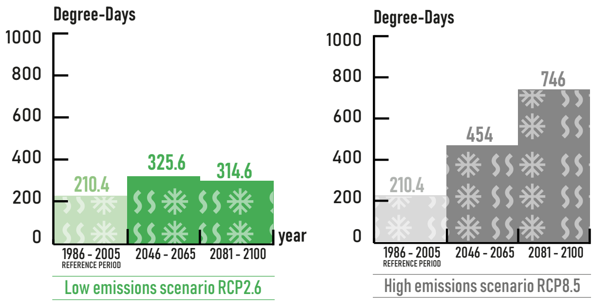


Figure 11.14. Cooling Degree Days (CDD). Ensemble mean of EURO-CORDEX simulations.

Source: SOCLIMPACT project deliverable D4.3. Atlases of newly developed indexes and indicator.

11.3.4. Maritime Transport

11.3.4.1. Sea Level Rise (SLR)

Sea Level Rise (SLR) is one of the major threats linked to climate change. It would induce permanent flooding of coastal areas with a profound impact on society, economy and environment. Moreover, an increase in the mean sea level would result in a larger impact of coastal storms with the consequent increase of risk. The results are presented in terms of mean sea level rise. For Sicily, the SLR ranges from 22.96 cm (RCP2.6) to 62.5 cm (RCP8.5) at the end of the century (see **Figure 11.15**).

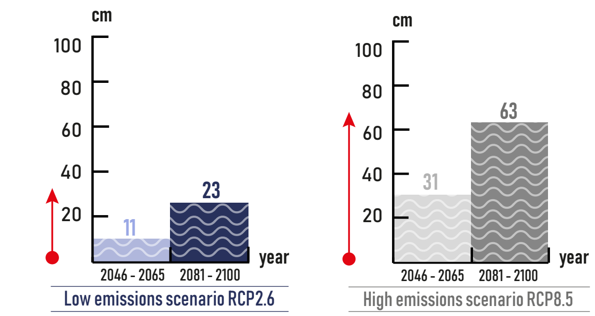


Figure 11.15. Mean sea level rise (in cm) with respect to the reference period (1986-2005). Own elaboration based on global and regional simulations.

Source: SOCLIMPACT project deliverable D4.4b - Report on storm surge levels.

11.3.4.2. Storm surge extremes

Storm surge events, characterized by positive extreme sea levels and mechanically forced by atmospheric pressure and wind are the main responsible for coastal flooding, especially when combined with high tides.

To date, the only ensemble populated with enough number of members to compute meaningful statistics on climate projections is the one produced for the Mediterranean by Lionello *et al.* (2017). This ensemble consists on 6 simulations run with the HYPSE model at 1/4° of spatial resolution and forced by the high-resolution wind fields from the MedCORDEX ensemble, which in turn is nested into CMIP5 global simulations. The simulations are run for the period 1950-2100, thus covering the historical period as well as the whole 21st century. Complementary, the ensemble includes three hindcast simulations that are used to establish present reference levels. Storm surge could decrease an amount of 20% under RCP8.5 (far future) (see **Figure 11.16**).

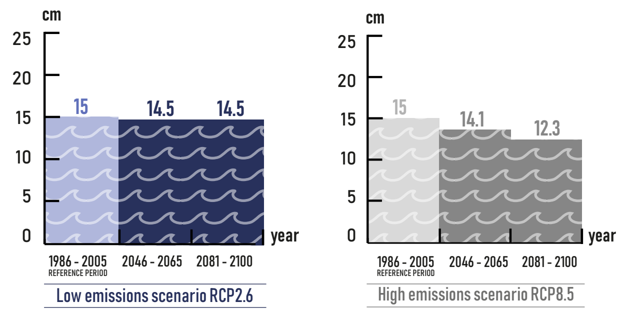


Figure 11.16. 99th percentile of atmospherically forced sea level (in cm) averaged for the hindcast period, the near future (2046-2065) and the far future (2081-2100) under scenarios RCP2.6 (with scaling approximation) and RCP8.5, relative change in brackets.

Source: SOCLIMPACT project deliverable D4.4b - Report on storm surge levels.

11.3.4.3. Wind extremes

The wind extremity index NWIX98 is defined as the number of days per year exceeding the 98th percentile of mean daily wind speed. This number decreases in the far future with a strongest value under RCP8.5 (16%). Like the NWIX98, the 98th percentile of daily wind speed, WIX98, decreases but with a more significant magnitude for RCP8.5 (see **Figure 11.17**).

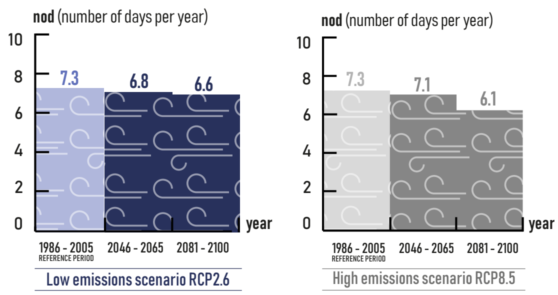


Figure 11.17. Wind Extremity Index (NWIX98). Ensemble mean of EURO-CORDEX simulations.

Source: SOCLIMPACT project deliverable D4.3. Atlases of newly developed indexes and indicator.

11.3.4.4. Wave extremes (99th percentile of significant wave height averaged)

Marine storms can have a negative impact on maritime transport, coastal-based tourism and aquaculture, among other activities. To illustrate this impact, the 99th percentile of significant wave height averaged has been chosen. A decrease in the extreme wave height is found being larger under scenario RCP8.5 (see **Figure 11.18**).

11.4. Risk Assessment

11.4.1. Tourism

11.4.1.1. Loss of attractiveness due to marine habitat degradation

Sicily ranks the best position regarding the climate change risk under analysis. The island does not outstand in any component of the risk, but neither shows critical pitfalls regarding it. With respect to the foundation species, the island holds the second largest surface, but lesser susceptible to sweater heating. This island also presents the most balanced tourist demand, as it treasures a wide range of cultural, social, landscape, gastronomic and historic resources to underpin a tourism industry not very dependent on the marine environment. All these factors together, but none of them particularly, make Sicily the most resilient island to the risk of its tourism industry being affected by seawater heating. The most salient weakness at this respect seems to be the seawater pollution due to a deficient capacity to treat sewage. Related investments should be a priority for this island.

The mentioned advantages and disadvantages of Sicily are depicted in the next figures. The further the criteria or sub-criteria is located from the centre of the graph, the more it affects the risk (see **Figure 11.19** and **Figure 11.20**).

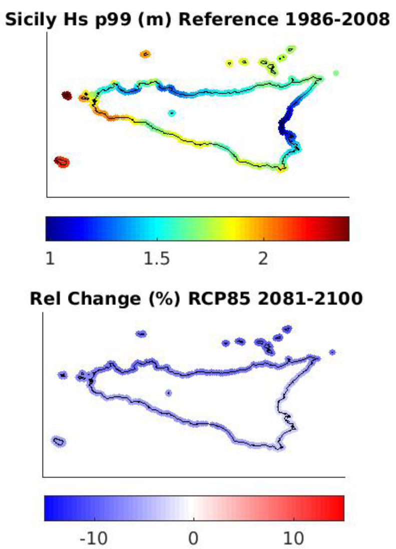


Figure 11.18. The 99th percentile of significant wave height averaged for the reference period and the relative change for the RCP8.5. Own elaboration based on global and regional simulations.

Source: SOCLIMPACT project deliverable D4.4b - Report on storm surge levels.

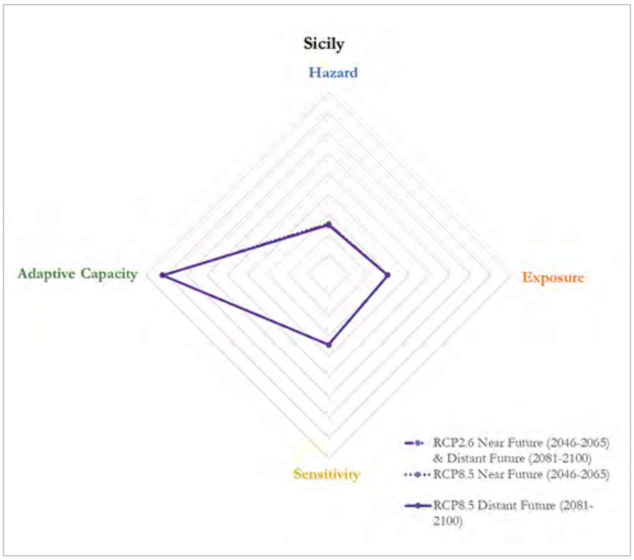


Figure 11.19. Global weights of each criteria and sub-criteria in the final score.

Source: SOCLIMPACT Deliverable Report – D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

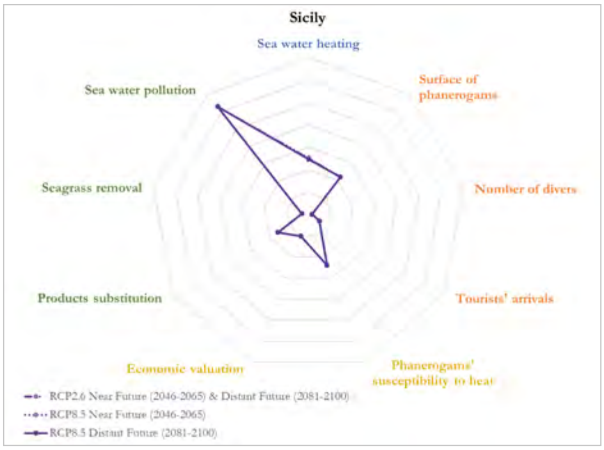


Figure 11.20. Global weights of each criteria and sub-criteria in the final score.

Source: SOCLIMPACT Deliverable Report – D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

11.4.1.2. Loss of attractiveness due to increased danger of forest fires in touristic areas

For the reference period (1986-2005), the overall risk of forest fires is low for Sicily. It is maintained low in the near future (2046-2065) for both RCPs and even for RCP2.6 in the distant future (2081-2100). However, for RCP8.5 in the distant future, it moves to an overall medium risk of forest fires. This is mainly due to the increase of fire danger (hazard) for the end of the century and the medium score of exposure (population density and extense cultivated areas). Despite this, having the lowest score of flammability index prevents forest fires from becoming at greater risk in the future (see **Figure 11.21** and **Figure 11.22**).

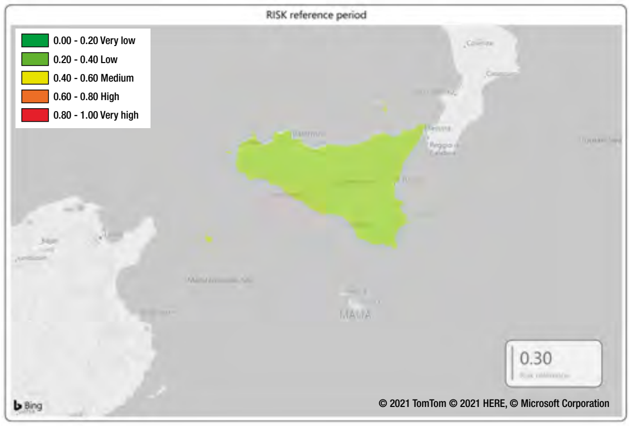


Figure 11.21. Risk score for the reference period.

Source: SOCLIMPACT Deliverable Report – D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

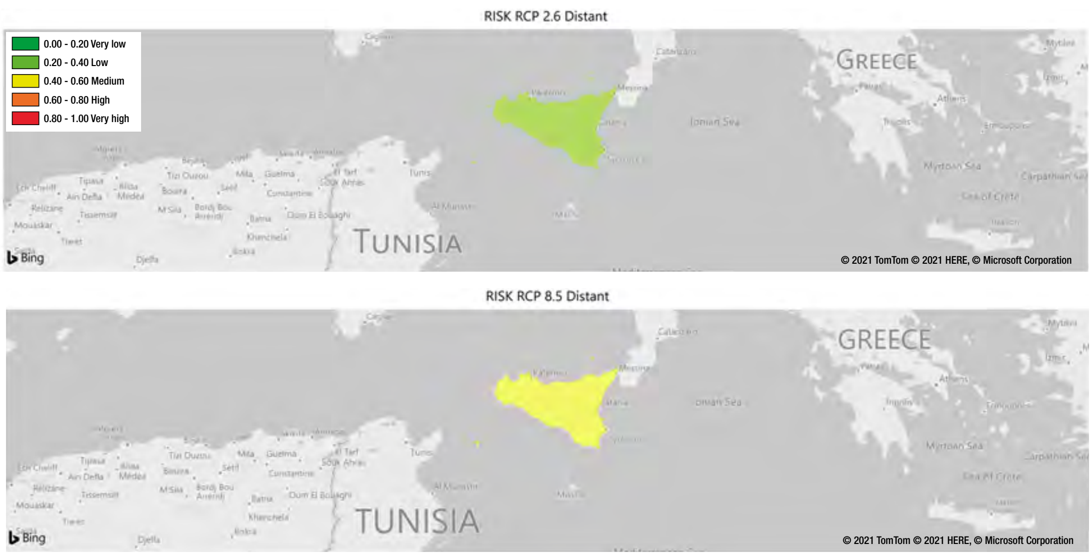


Figure 11.22. Risk score at the end in the distant future (2081-2100) under RCP2.6 (Ambitious Mitigation Policies) and RCP8.5 (Business as usual).

Source: SOCLIMPACT Deliverable Report – D4.5. Design of a comprehensive approach to climate and climate-related risk information to policy makers and the general public.

11.4.2. Aquaculture

11.4.2.1. Risk of increased fragility of aquaculture activity due to extreme weather events

Results for the hazard induced by mean wave motion appear to classify most Mediterranean offshore farm locations as semi-exposed sites (unlike those in the Atlantic, which are offshore). The probability of occurrence of extreme events that might prove unendurable for infrastructures moderately lowers the cumulative hazard. Results for Sicily exhibit increased uncertainty, clearly deriving from the extreme event component (see **Table 11.4**).

Table 11.4. Risk results for impact chain "Extreme Weather Events" for the Mediterranean islands.

Risk	Best-case scenario					Worst-case scenario				
	Reference period	Mid century		End century		Reference period	Mid century		End century	
	Hist	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	Hist.	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Corsica	0.19	0.19	0.19	0.20	0.21	0.25	0.25	0.26	0.28	0.26
Cyprus	0.23	0.23	0.23	0.23	0.22	0.23	0.23	0.23	0.23	0.22
Malta	0.26	0.26	0.26	0.26	0.26	0.42	0.45	0.56	0.45	0.36
Sardinia	0.30	0.32	0.32	0.28	0.31	0.33	0.33	0.34	0.33	0.33
Sicily	0.20	0.20	0.20	0.20	0.20	0.30	0.34	0.33	0.33	0.26

11.5. Impacts on the Blue Economy Sectors

11.5.1. Tourism (Non-Market Analysis)

In order to analyse the reactions of tourists to the impacts of climate change and the preferences for adaptation policies, several hypothetical situations were posed to 290 tourists visiting Sicily, whereby possible climate change impacts were outlined for the island (i.e., beach erosion, infectious diseases, forest fires, marine biodiversity loss, heat waves, etc.) (see **Figure 11.23**).

Firstly, tourists had to indicate whether they would keep their plans to stay on the island or find an alternate destination if the impact had occurred, which allows predictions of the effects on tourism arrivals to be made for each island. Secondly, tourists were asked to choose between various

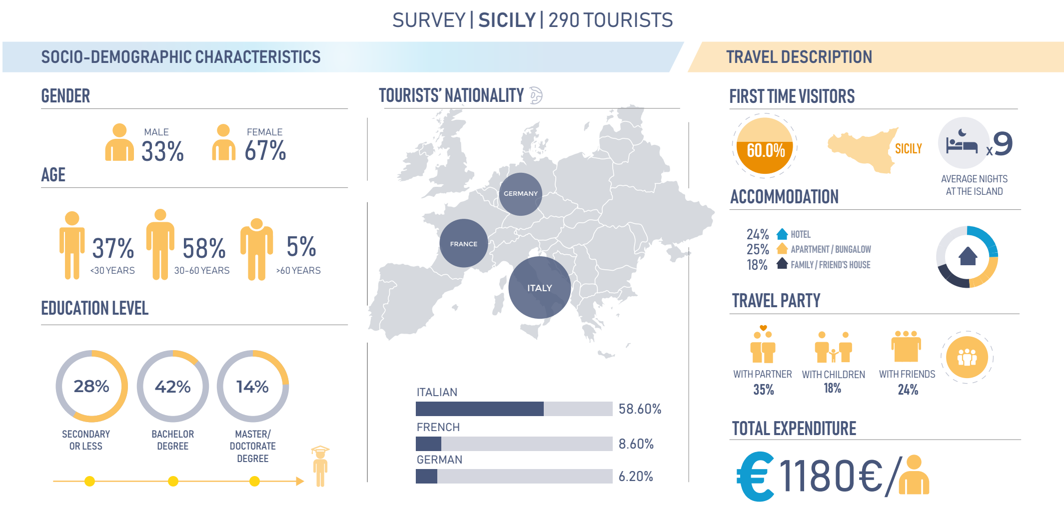


Figure 11.23. Socio-economic characteristics and travel description: tourists visiting Sicily.
Source: SOCLIMPACT Deliverable Report - D5.5. Market and non-market analysis.

policy measures funded through an additional payment per day of stay – the tourists' choices being an expression of their preferences for attributes/policies. To estimate the results, the conditional logit model was run by using the Stata software.

In general, data confirms that tourists are highly averse to risks of infectious diseases becoming more widespread (75.30 % of tourists would change destination). Moreover, they are not willing to visit islands where the cultural heritage is damaged due to weather conditions (52.40 %), where wildfires occure more often (52.10 %) or where water is scarce for leisure activities (52.10 %). Consequently, policies related to the prevention of infectious diseases (3.5 €/day), the protection of the cultural heritage (3.5 €/day), and the marine habitats restoration (3.2 €/day) are the most valued, on average, by tourists visiting this island.

Although climate change impacts are outside the control of tourism practitioners and policy-makers, they can nevertheless utilise this knowledge to improve the predictability of the effect that certain adaptation policies and risk management strategies, and develop their plans accordingly (see **Figure 11.24**).

The impact of increased temperatures and heat waves on hotels' prices and revenues

In order to assess how the variation in temperature impacts the tourism sector through changes in tourism demand, our research question was: "How do increasing temperatures (and heat waves) impact prices and, more in general, expenditure of tourists?" Arguably, when temperatures grow, tourists adjust their behaviour: they might switch destination, or they might stay longer or shorter depending on their attitudes and preferences. In turn, all these changes modify the market equilibrium, pushing tourism companies to adjust their prices to re-establish the equilibrium between demand and supply. The change in demand and the change in price determine the change in tourism expenditure which is, from the destination's perspective, tourism revenue.

We monitored current weather conditions posted on several weather forecast providers and daily prices posted on Booking.com by hotels. We then estimated the link between daily temperature and daily price, controlling for all the other factors affecting prices. We finally applied these estimates to the increase in the number of days with excessive tempera-

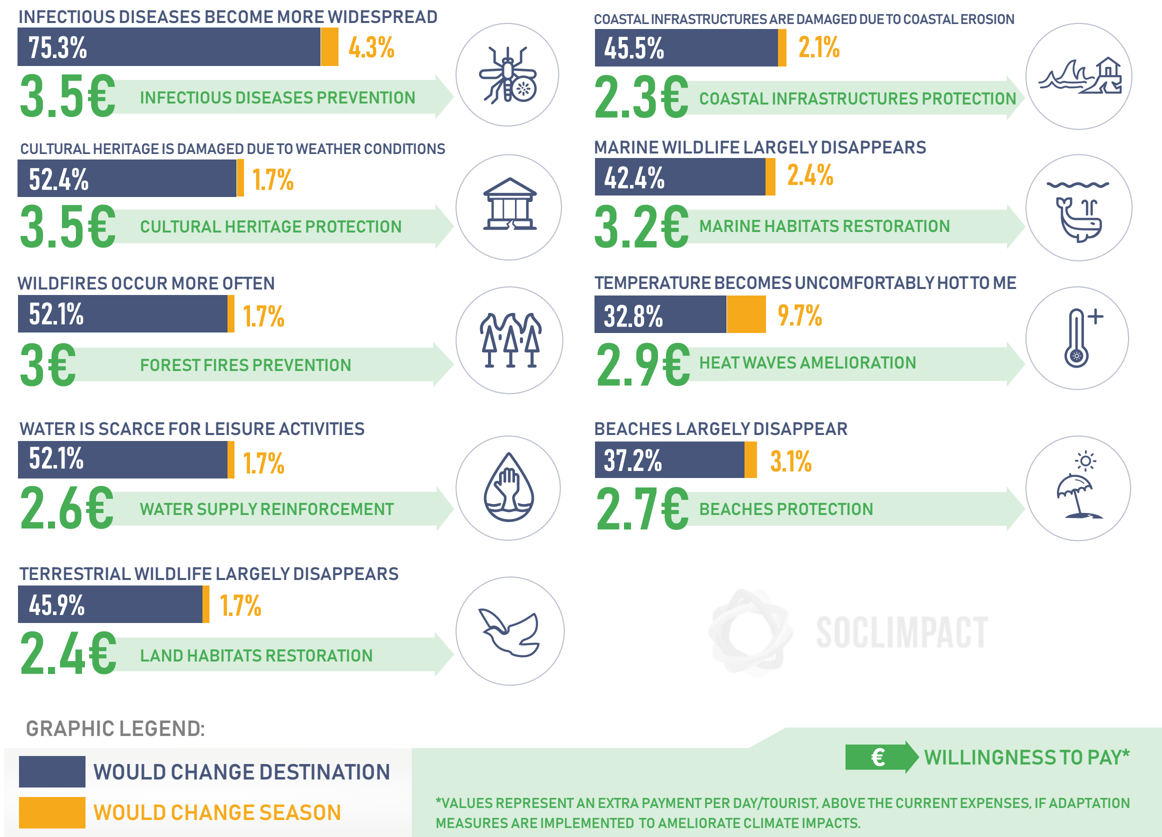


Figure 11.24. Tourists' response to climate change impacts and related policies: tourists visiting Sicily.

Source: SOCLIMPACT Deliverable Report - D5.5. Market and non-market analysis.

ture projected for the future in two scenarios (RCP2.6 and RCP8.5) and in two time horizons (near future, about 2050; distant future, about 2100).

Among the different indicators linked to thermal stress, we focus on two: the number of days in which the temperature is above the 98th percentile and the number of days in which the perceived temperature is above 35 °C. Although the impact for both indices was computed, in this document we only report the second one (named Humidex) because it is the most intuitive and because human thermal stress is more related to the absolute value of the temperature than its deviation from some pre-determined distribution. We assumed that thermal stress appears when the perceived temperature grows above 35 °C.

As thermal stress is delimited in the summer months, and this is when the great majority of tourists arrive in these islands, the whole analysis has been carried out in six months only: from May to October included. In other words, we assume that there is no thermal stress (and hence, no impact on tourism) in the rest of the year.

Initially, three islands were investigated: Corsica, Sardinia, and Sicily, given the massive amount of potential data. We focused the analysis in three specific areas, represented in the map below: the south-east area of Corsica (between Porto Vecchio and Boniface), the north-east area of Sardinia (Costa Smeralda) and the south-east area of Sicily (the coastal area of Catania and Siracusa provinces). Arguably, these are among the most important coastal tourism areas of these islands. Overall, 60 hotels (for a total of about 240,000 observations) were monitored in Corsica; 150 hotels (for a total of about 620,000 observations) were monitored in Sardinia; 129 hotels were monitored in Sicily (for a total of about 726,000 observations) over the period May 1, 2009 – October 31, 2009 (see **Figure 11.25**).

Nowadays, 28.49% (column 1 of the table below) of "summer" days (days in the period between May 1 and October 31) have a Humidex higher than 35 °C in the area under investigation (coastal area of Catania and Siracusa).

In the future, this share (column 3) will increase to about 37-38 % in RCP2.6, to 40.60 % in RCP8.5 (near), and to 65.04 % in RCP8.5 (distant). Consequently, demand for holidays in Sicily will increase, and the new equilibrium shows an increase in the average price posted by hotels in the destina-

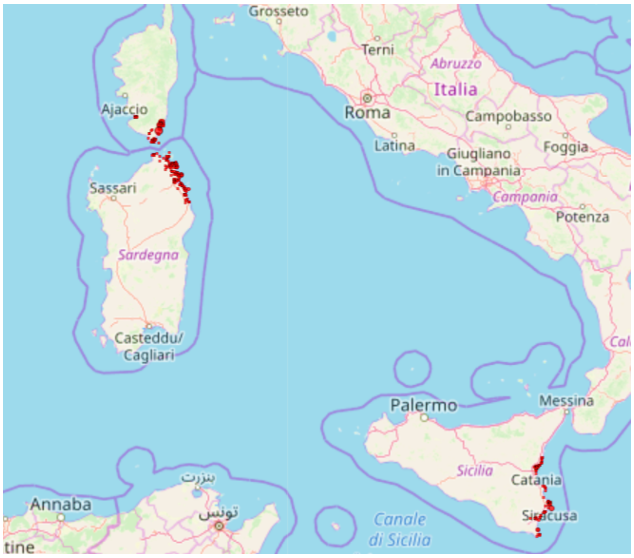


Figure 11.25. Map of the region.

Source: SOCLIMPACT Deliverable Report - D5.3. Data Mining from Big Data Analysis.

tion (column 4) and an increase in overnight stays (column 5, this is estimated using the past correlation between average prices and occupancy rates in hotels, data provided by STR). The joint impact of price and demand will lead to an increase in hotels revenues (last column of the table) and, assuming that the change in revenues spreads to the other tourism products in a similar way, an increase in tourism revenues for the whole destination will be recorded. Hence, the estimation reported in the last column of the table below can be interpreted as the percentage increase in tourism revenues for the island (see **Table 11.5**).

According to these findings, the average increase in temperature, which is correlated to a growing thermal stress for tourists, brings an economic advantage to tourism destinations. This is only an apparent contradiction with previous findings. This study does not neglect the fact that if islands are too hot, tourists will choose to move to other (cooler) destinations, that theoretically exist. In this study, the underlying assumption is instead that growing temperatures are

Table 11.5. Estimation of increase in average price and revenues for Sicily.

Actual share of days in which Humidex > 35 degrees	Future scenario considered	Days in the corresponding scenario in which Humidex > 35 degrees	Increase in the average price	Increase in the tourism overnight stays	Increase in tourism revenues
28.49%	RCP 2.6 near	37.53%	0.4%	0.1%	0.5%
	RCP 2.6 far	38.41%	0.5%	0.1%	0.6%
	RCP 8.5 near	40.60%	0.6%	0.1%	0.7%
	RCP 8.5 far	65.04%	1.7%	0.3%	2.1%

Source: SOCLIMPACT Deliverable Report - D5.3. Data Mining from Big Data Analysis.

a global issue, thereby not modifying the relative position of a destination. Then, the increase in tourism (and tourism revenues) stem from the fact that, when the temperature is too hot, people would prefer to move to coastal areas (where the climatic conditions are more bearable) than staying inland or in cities. Future trends will also facilitate this pressure of tourism demand (think about the spreading of smart working activities where, in principle, the worker can relocate wherever he/she wants).

11.5.2. Aquaculture

The effects of increased sea surface temperatures on aquaculture production were calculated using a lethal temperature threshold by species, and considering the production share of the region. Four different future scenarios shown by IPCC estimations (RCP2.6 and RCP8.5 near and distant) were analysed, which correspond to four water temperature increases in the region (mean values), with respect to the reference period.

To do this, we assume two main species cultured in this region: Seabream (SB) and Tuna (T), and a model of production function, calculating the monthly biomass production which depends on the monthly water temperature. Results are presented on a yearly basis (mean values). In order to facilitate the interpretation of the results, we present the value of production of the last year available, for which we calculate the new values under the different climate change scenarios.

As expected, the production levels (tons) will decrease for both, low and high emissions scenarios. In both cases, the average annual temperatures are projected in levels below 23 °C and 24 °C, which are the thresholds of thermal stress for Bluefin tuna and Seabream species (see **Figure 11.26**).

4,794.90 *	4,699.00 ▼ (-2%)	4,699.00 ▼ (-2%)
19.00	19.80	19.80

PRODUCTION SHARE	%
SEABREAM	30
SEABASS	26
MED, MUSSEL	44

4,794.90 *	4,574.33 ▼(-4.6%)	4,161.97 ▼(-13.2%)
19.00	20.40	21.60

Figure 11.26. Estimations of changes in aquaculture production (tons), due to increased sea surface temperature.

Source: SOCLIMPACT Deliverable [Report - D5.6]. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

11.5.3. Energy

Climate change may impose welfare reductions to the European islands' societies by affecting thermal comfort. Cooling Degree Days (CDD) are a measure of how much (in degrees), and for how long (in days), outdoor air temperature is higher than 21 °C. The CDD is used as a measure of the energy needed to cool buildings. The increase in CDD and the energy demand (GWh/year) for cooling are estimated for the islands under different scenarios of global climate change.

Under the high emissions scenario, it is expected that the CDD increase to 5112 CDD[1]. Under this situation, the increase in cooling energy demand is expected to be 235 % (see **Figure 11.27**).

[1] The indicator is computed by multiplying the number of days exceeding the threshold by the difference in temperatures. For example, the CDD for 100 days at 20 °C is computed as 100* (20-18) = 200 CDD.

The Standardized Precipitation Evapotranspiration Index (SPEI) is analysed as a representative indicator for increases in water demand for islands' residents, tourists and agriculture, while it also provides an indication on the available water stored in dams or underground resources. To estimate the increase of energy demand due to the increase in water demand, it was assumed that most of the islands will have to produce desalinated seawater (or groundwater) to meet further increases of demand. Thus, the estimation of the increase in energy demand (GWh/year**)** to produce more drinking water has been done based on the energy consumption required to desalinate seawater.

Under the low emissions scenario (RCP2.6), there are not significant changes in the SPEI indicator, that will remain in its ¨normal¨ level, as it is nowadays. Nevertheless, an increase of 24 % in desalination energy demand is expected. Under RCP8.5, the scenario alerts on a severe aridity leading to an increase of 138 % of the energy demand (see **Figure 11.28**).

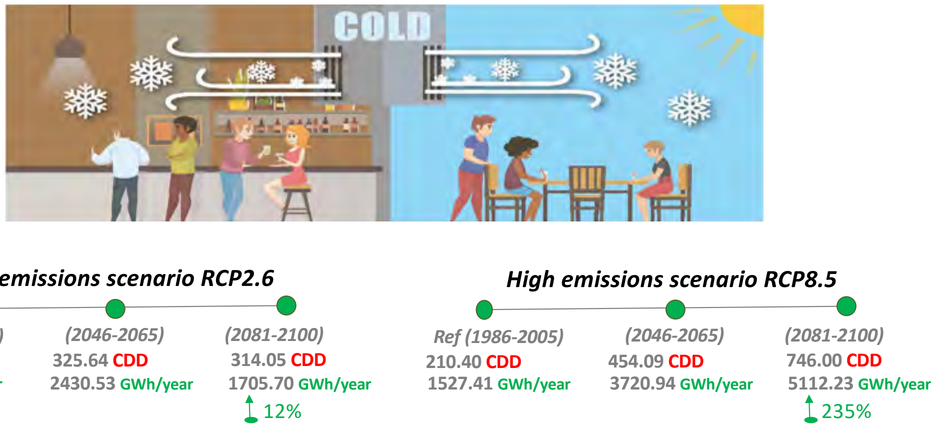


Figure 11.27. Estimations of increased energy demand for cooling in Sicily under different scenarios of climate change until 2100.

Source: SOCLIMPACT Deliverable [Report - D5.6](). Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

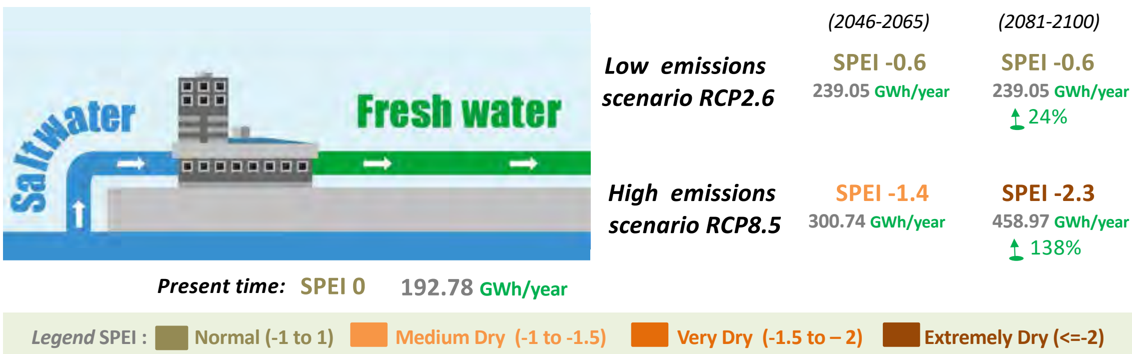


Figure 11.28. Estimations of increased energy demand for desalination in Sicily under different scenarios of climate change until 2100.

Source: SOCLIMPACT Deliverable [Report - D5.6](). Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

11.5.4. Maritime Transport

For maritime transport, it has been estimated the impact of Sea Level Rise on ports' operability costs of the island. The costs have been calculated with reference to 1 meter; this is, the investment needed to increase the infrastructures' height by 1 meter. There is not necessarily a strict correspondence between the SLR and the required elevation of port infrastructures, which also depends on the coastal hydrodynamic and the shape of dikes of each port. By experts' recommendation, we have assumed that 1 meter increase in port height is required to cope with the SLR under RCP8.5

scenario of emissions. Extrapolation for other RCP scenarios is then conducted based on proportionality.

The starting point was the identification of the principal ports in each island (economic relevance). Second, the analysis of the different port areas (exterior, ramps, oil, etc.), and their uses. Third, the elevation costs were estimated per each area and port separately (considering 1 meter elevation). Thus, the costs of 1 meter elevation presented are the sum of all areas and ports analysed, and including the rest of the ports of the island (if applicable) based on proportionality. Estimations consider that all ports areas of the entire zone should be elevated at the same time. In other words, the economic values can be interpreted as the depreciation (amortization) costs of the investment needed to increase all ports' infrastructures' in the island for 125 years time horizon. No discount rate has been applied.

As expected, the rising of sea levels will affect the sector, as new investment will be needed to keep ports' operability. Under the high emissions scenario, it is expected that these costs could increase 3.6 million of euros per year until the end of the century (see **Figure 11.29**).

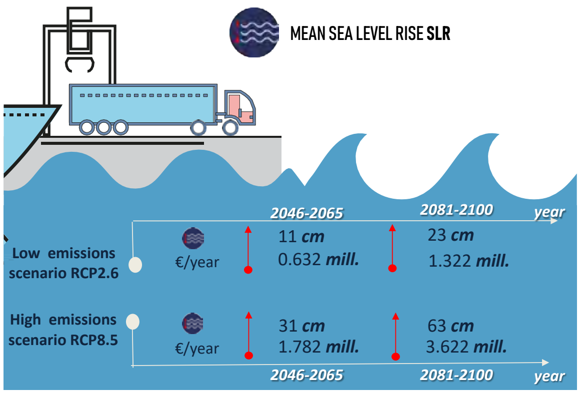


Figure 11.29. Increased costs for maintaining ports' operability in Sicily under different scenarios of SLR caused by climate change until 2100.

Source: SOCLIMPACT Deliverable Report D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

11.6. Impacts on the Island's Economic System

In order to assess the socio-economic impacts of biophysical changes for the island of Sicily, we have used the GEM-E3-ISL model, a single-region, multi-sectoral general equilibrium model based on the principles of neo-classical theory, and GINFORS, a macro-econometric model based on the principles of post-Keynesian theory.

Both models include 14 sectors of economic activity, with an emphasis on services and specifically on those composing the tourism industry. The GEM-E3-ISL model also includes endogenous representation of labor and capital markets as well as bilateral trade flows by sector.

Changes in the mean temperature, sea level and precipitation rates are expected to affect energy consumption, tourism flows and infrastructure developments. These impact-chains have been examined and quantified under two emission pathways: RCP2.6, which is compatible with a temperature increase well below 2 °C by the end of the century, and RCP8.5, which is a high-emission scenario. The impact on these three factors was used as input in the economic models, which then assess the effects on GDP, consumption, investments, employment, etc.

In total, 18 scenarios have been quantified for Sicily. The scenarios can be classified in the following categories:

1. Tourism scenarios: these scenarios examine the reduction in tourism revenues due to changes in human comfort as captured by the hum-index, the degradation of marine environment, the increased risk of forest fires and beach reduction. The aggregate tourism scenario (TOUR-SC6) assesses the economic impacts of a simultaneous change of all (the above-mentioned) factors.
2. Energy scenarios: the aggregate energy scenario (ENER-SC3) assessed the impacts on regional economic performance of increased total electricity demand driven by cooling and water desalination demand.
3. Infrastructure scenario: this scenario assesses the impact of port infrastructure damages (INFRA-MAR).

Table 11.6. Aggregate scenario –inputs.

	Tourism revenues (% change from reference levels)	Electricity consumption (% change from reference levels)	Infrastructure damages (% of GDP)
RCP2.6 (2045-2060)	-7.24	10.50	-0.04
RCP2.6 (2080-2100)	-10.06	3.10	-0.04
RCP8.5 (2045-2060)	-13.76	25.30	-0.10
RCP8.5 (2080-2100)	-38.44	43.50	-0.12

Source: SOCLIMPACT Deliverable Report - D5.6. Integration and coordination of non-market and big data analysis of economic values resulting from climate change impacts to GEM-E3-ISL and GINFORS models.

4. Aggregate scenarios: these scenarios examine the total impact of the previous-described changes in the economy.

In the aggregate scenario, we examine the impacts of a simultaneous change in electricity consumption, tourism revenues and infrastructure damages. The scenario specifications for the two climatic variants are presented below (see **Table 11.6**).

The theoretical and structural differences of the two models mean that this study produces is a reasonable range of impacts, given the uncertainty embodied in economic analysis and especially in the long-term.

In GEM-E3-ISL, the economy is in equilibrium at each point in time. Prices adjust to ensure that supply equals demand (market clearing) and capital is fully used; however, the model allows for equilibrium unemployment as it takes into account labor market rigidities. The impacts are driven mainly by the supply side through changes in production costs which influence relative prices; hence, competitiveness and trigger substitution effects. The GEM-E3-ISL model assesses the impacts on the economy up to 2100.

The macro-econometric type of models, such as GINFORS, do not require that all markets are in equilibrium; idle capital and involuntary unemployment are some other features of this type of models where the results are driven mainly by adjustments in the demand side of the economy. The GINFORS assesses the impacts on the economy up to 2050.

With respect to GDP, the estimated change compared to the reference case is between -0.5% and 0.05% in the RCP2.6 in 2050 and between -1.1% and -1.6% in the RCP8.5. The cumulative reduction over the period 2040-2100 is estimated (by GEM-E3-ISL) to be equal to 0.54% in the RCP2.6 and 2.6% in the RCP8.5. In GINFORS, increased investments are the driver of GDP increases in the RCP2.6, while in the GEM-E3-IS model increased investments in electricity crowds-out other productive investments and drive capital prices higher resulting in competitiveness losses; hence, these two effects cancel out the positive impact of increased investments (see **Figure 11.30**).

With respect to sectoral impacts, both models show a significant decrease in the activity of tourism related sectors and an increase in the activity of the non-service sectors, highlighting the opportunities for the development of other secondary sectors' activities (see **Figure 11.31**).

Overall, employment falls in the economy and especially in tourism related sectors. In GEM-E3-ISL, increases in employment in non-tourism related activities are associated with labor costs reductions (as wages fall and their competitiveness increases) and a consequent substitution of capital with labor. Employment falls on average by 0.1% in the RCP2.6 in the RCP8.5 (see **Figure 11.32**).

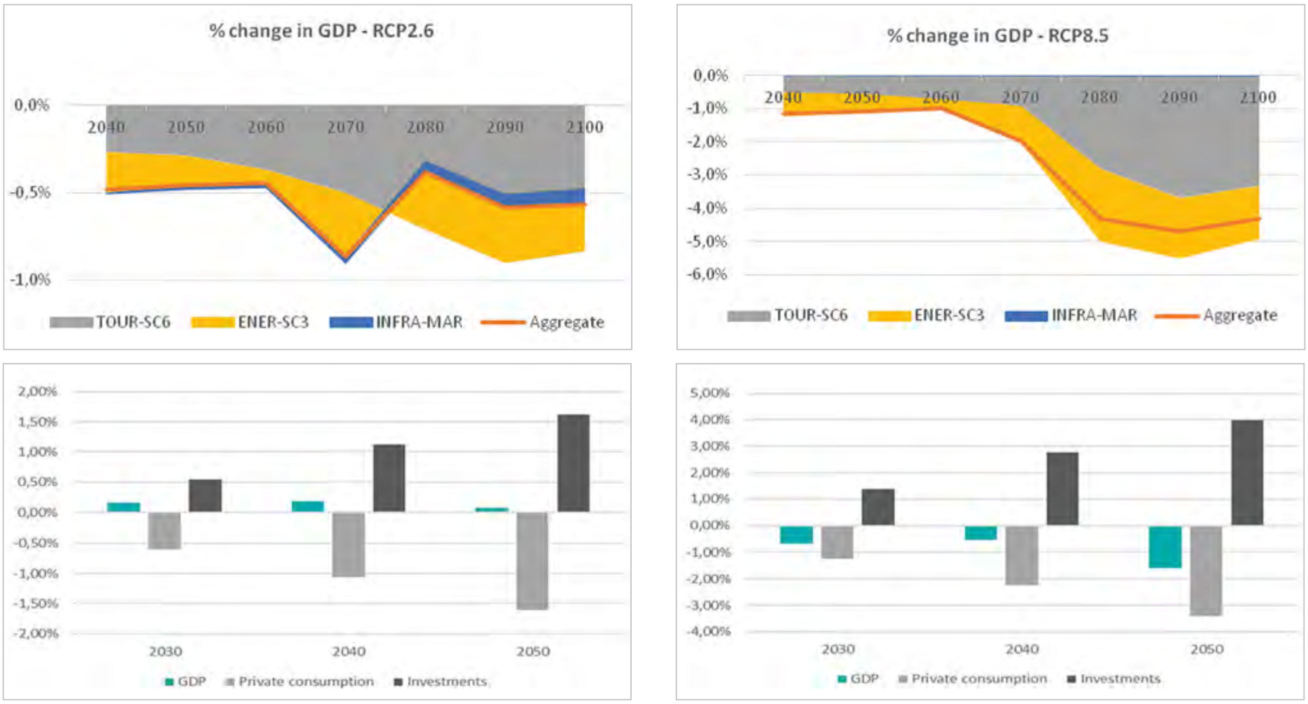


Figure 11.30. Percentage change in GDP. GEM-E3-ISL results (above), GINFORS (below).

Source: own calculation.

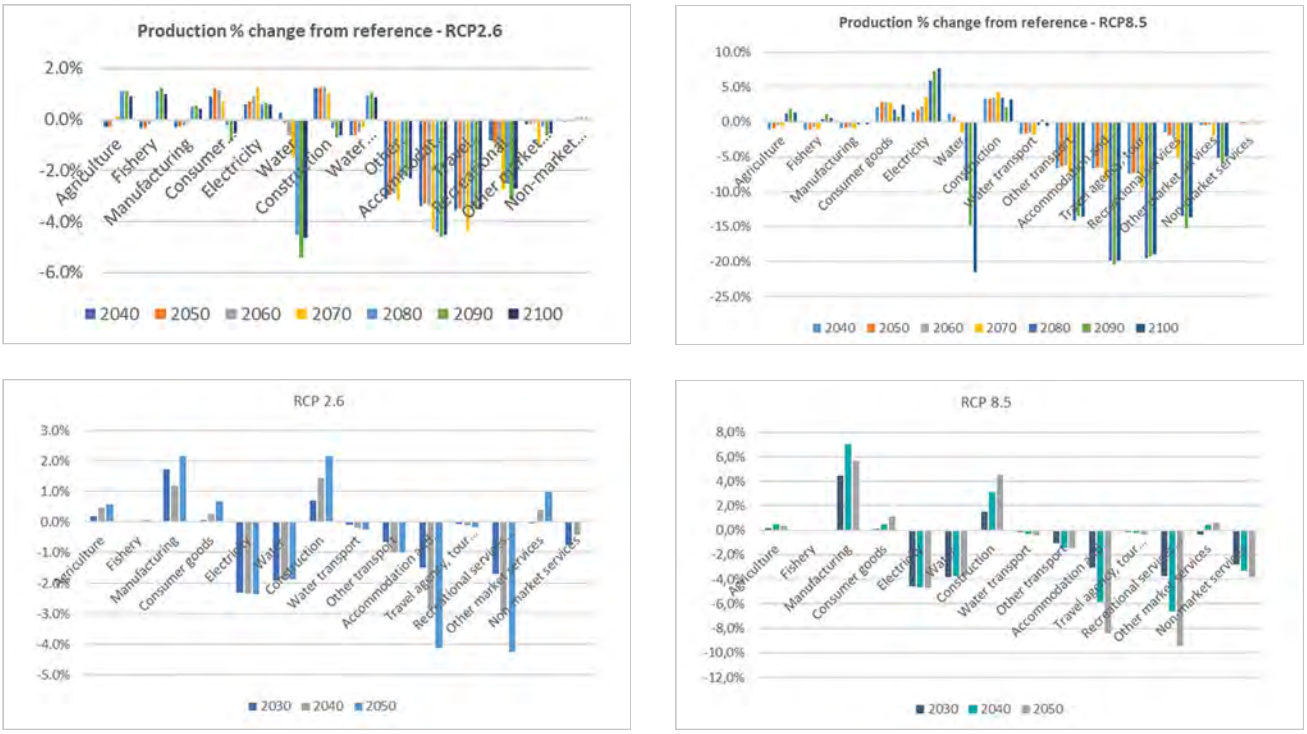


Figure 11.31. Production percentage change from reference. GEM-E3-ISL results (above), GINFORS (below).
Source: own calculation.

Figure 11.32. *Employment percentage change from reference.* GEM-E3-ISL results (above), GINFORS (below).
Source: own calculation.

11.7. Towards Climate Resiliency

Over the last few years, the country has been dedicated to support and provide a robust analytical basis for the National Integrated Energy and Climate Plan (2018):

- A BASE scenario that describes an evolution of the energy system with current policies and measures;
- A PNEC scenario that quantifies the strategic objectives of the plan. The PNEC tables illustrate the main objectives of the 2030 plan on renewables, energy efficiency and greenhouse gas emissions as well as the main measures envisaged to achieve the objectives of the plan.

The National Strategy for Adaptation to Climate Change (SNAC) was approved and adopted in 2015. The latest has been the National Plan of Adaptation to Climate Change (PNACC) (July 2017), which identifies and discusses the main objectives to be pursued, as well as the necessary steps, for each one of the socio-economic and environmental sectors of interest, based on the climatic and impact analyses to face the effects of the expected climate changes. From the sector analysis, over 350 actions emerged that were collected in a single database that contains detailed analytical information for each individual action and different selection keys for the actions to allow easy search and consultation.

Lately, in 2020, Sicily was selected among some mediterranean islands, together with Crete and Cyprus, to simulate the impacts of climate change on crop production and the effectiveness of selected adaptation options in decreasing vulnerability to climate change of three Mediterranean islands. This project, Adaptation to Climate Change Impacts on the Mediterranean Islands' Agriculture –ADAPT2CLIMA– (2020), aims to facilitate the development of adaptation strategies for agriculture by deploying and demonstrating an innovative decision support tool. The islands were selected for two reasons. Firstly, they figure among the most important cultivation areas at national level. Secondly, they exhibit similarities in terms of location (climate), size, climate change threats faced (coastal agriculture, own water resources), agricultural practices, and policy relevance.

There are 13 cross-cutting actions that are common to all the sectors analyzed and which have a national value, together with more specific actions for each sector. The actions identified for each sector are associated with the impacts detected in the previous analyzes, the adaptation targets to be pursued and the homogeneous climatic areas of implementation, suggested on the basis of the RCP4.5 climate scenario identified as the reference scenario.

Nevertheless, different limitations and barriers, respectively experienced by individuals, organizations and local governments have been identified. Research on climate change impacts has so far been limited to general conclusions at the national level, without focusing on regional and local climate change and its impact. Even less progress has been made in the field of adaptation, as no adaptation plans have been put in place to identify necessary and specific measures for the local context. From the point of view of individuals, a general low personal understanding of climate change and its impacts exists.

Considering organizations (both private and public), we can highlight different barriers:

- Inadequate funds for adaptation, especially the financial ones.
- Uncertainty around the scale of the climate changes and the concrete risks.
- Lack of locally relevant and practical information about potential climate impacts.
- Limited financial resources both for medium sized organizations and local governments.
- Culture of the organization.

Specifically for local governments, planning seems to be a difficult task.

Furthermore, there is a lack of reliable statistics and information related to exposure and vulnerability of the island to climate change. These are important components that worsen climate risks and respond to human interventions (more pressure). The island's adaptation focus should be, first, the development of reliable information systems for the periodic monitoring of these components.

11.7.1. Policy Recommendations

A stakeholders consultation process was carried out in the island, aiming to propose, analyse and rank alternative adaptation measures for the island. The profile of the individuals participating in these focal groups involved policy and decision-makers, practitioners, non-governmental and civil society organisations, science experts, private sector, business operators and sector regulators at island level.

The main aim of these meetings was:

1. Identify and present the characterized packages of adaptation and risk management options for the island.
2. Develop detailed integrated adaptation pathways, in three timeframes: Short term (up to 2030), Mid-century (up to 2050) and End-century (up to 2100).
3. Evaluate and rank adaptation options for 4 blue economy sectors in the island (energy, maritime transport, aquaculture and tourism).
4. To this aim, stakeholders utilized five evaluation criteria to rank the proposed measures:

- Cost efficiency: Ability to efficiently address current or future climate hazards/risks in the most economical way.
- Environmental protection: Ability to protect the environment, now and in the future.
- Mitigation win-wins and trade-offs: Current ability to meet (win-win) or not (trade-off) the island / archipelagos mitigation objectives.
- Technical applicability: Current ability to technically implement the measure in the island.

- Social acceptability: Current social acceptability of the measure in the island.

Four scenarios of intervention were analysed, called Adaptation Policy Trajectories (APT), which are different visions of future policy adaptation choices:

- APT A Minimum Intervention - Low investment, low commitment to policy change.
- APT B Economic Capacity Expansion - High investment, low commitment to policy change.
- APT C Efficiency Enhancement - Medium investment, medium commitment to policy change
- APT D System Restructuring - High investment, high commitment to policy change.

It was assumed that adapting to climate change may range from minimal to high cost, and from requiring a small or incremental change to a significant transformation from the *status quo*. However, not all APT scenarios were considered in all islands, especially when their stakeholders had a clear vision on the types of measures with greatest viability. Therefore, the final set of proposed adaptation measures are framed in the islands' socio-economic and political context, have a sectoral perspective, and respond to the islands' future scenarios of climate change. At the same time, the involvement of regional stakeholders in policy design allows them to engage in the effective implementation of climate actions on their island.

In Appendices from K to N, a brief explanation of each adaptation option can be found, classified by type or class: Vulnerability Reduction, Disaster Risk Reduction, Social Ecological Resilience, and Local Knowledge. The latest group refers to very specific measures proposed by stakeholders in each island to ratify the needs.

11.7.1.1. Tourism

Overall, the adaptation pathways for the tourism sector in Sicily are characterized by a significant heterogeneity across the four potential Adaptation Policy Trajectories (APTs) and across adaptation objectives.

The main measures selected to address vulnerability reduction indicate that the region is initially centred on the development of sustainable approach in short, medium, and long term. Indeed, especially in APT C, the goal is address a circular economy system and sustainable economic activities. But the priority is for the natural, social, physical and human capital rather than the financial one. This last one is considered residual in this class and mainly for the short and long term in APT B and D. The selection of the financial incentives to retreat in the end of the century is related with the perception that the risks will continue or increase over time. The diversification of the activities and products are the desired option for all timeframes and APTs.

For Disaster Risk Reduction, and to manage long term risk, the decisions need to be sensible to the level of investment and reflect the climate change risk identified for the region. Pre-disaster early recovery planning is a priority for the region in the opposite scenarios, that is APT A and D, for the medium and long term. In general, for this class, the options are selected for the medium or long term and with a preference for the planning tools. This result highlights a great attention towards a better management with a long-term planning. In the other case, a different combination of investment and commitment is considered in respect of the first two options.

In Social-Ecological Resilience, the most selected option that is adaptive management of natural habitats, included in the cultural services. This measure is in APT C for all the times, then is considered a priority, now and in the future, but only with low investments and a medium level of commitment in this direction. All the measures of this class are mainly selected for the medium and long term and with a certain combination of investment and commitment, then often for APT B and C. The actions concerning the rivers represent a priority in respect of those ones on the sea, and there is a special attention to the planning and monitoring activities. This indicates that the need to prevent negative effects is considered urgent (see **Table 11.7**).

Table 11.7. Proposed adaptation options for tourism in Sicily.

APT A – Pathway	Short-term (up to 2030)	Mid-century (up to 2050)	End-of-century (up to 2100)
Minimum Intervention low investment, low commitment to policy change — This policy trajectory assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts	Public awareness programmes	Activity and product diversification	
	Coastal protection structures	Drought and water conservation plans	
	Fire management plans	Health care delivery systems	
	Post-disaster recovery funds	Pre-disaster early recovery planning	
	Adaptation of groundwater management		Monitoring, modelling and forecasting systems

Table 11.7 (Cont.). Proposed adaptation options for tourism in Sicily.

<table>
<tr><td rowspan="7">APT B – Pathway
—
Economic Capacity Expansion
high investment, low commitment to policy change
—
This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td>Economic Policy Instruments (EPIs)</td><td colspan="2">Financial incentives to retreat from high-risk areas</td></tr>
<tr><td>Public awareness programmes</td><td colspan="2">Activity and product diversification</td></tr>
<tr><td colspan="2">Beach nourishment</td><td>Desalination</td></tr>
<tr><td>Coastal protection structures</td><td colspan="2">Drought and water conservation plans</td></tr>
<tr><td>Adaptation of groundwater management</td><td colspan="2">Monitoring, modelling and forecasting systems</td></tr>
<tr><td>Dune restoration and rehabilitation</td><td colspan="2">River rehabilitation and restoration</td></tr>
<tr><td rowspan="10">APT C – Pathway
—
Efficiency Enhancement
medium investment, medium commitment to policy change
—
This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td colspan="2">Activity and product diversification</td><td>Public awareness programmes</td></tr>
<tr><td colspan="2">Local circular economy</td><td>Tourist awareness campaigns</td></tr>
<tr><td colspan="3">Local sustainable fishing</td></tr>
<tr><td colspan="2">Coastal protection structures</td><td>Drought and water conservation plans</td></tr>
<tr><td colspan="2">Mainstreaming Disaster Risk Management</td><td>Using water to cope with heat waves</td></tr>
<tr><td>Adaptation of groundwater management</td><td colspan="2">Monitoring, modelling and forecasting systems</td></tr>
<tr><td>Dune restoration and rehabilitation</td><td colspan="2">River rehabilitation and restoration</td></tr>
<tr><td colspan="2">Adaptive management of natural habitats</td><td>Ocean pools</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="8">APT D – Pathway
—
System Restructuring
high investment, high commitment to policy change
—
This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems</td><td>Short-term (up to 2030)</td><td>Mid-century (up to 2050)</td><td>End-of-century (up to 2100)</td></tr>
<tr><td>Economic Policy Instruments (EPIs)</td><td>Financial incentives to retreat from high-risk areas</td><td>Economic Policy Instruments (EPIs)</td></tr>
<tr><td colspan="2">Activity and product diversification</td><td>Public awareness programmes</td></tr>
<tr><td colspan="2">Local sustainable fishing</td><td>Water restrictions, consumption cuts and grey-water recycling</td></tr>
<tr><td>Coastal protection structures</td><td colspan="2">Drought and water conservation plans</td></tr>
<tr><td>Post-disaster recovery funds</td><td colspan="2">Pre-disaster early recovery planning</td></tr>
<tr><td>Adaptation of groundwater management</td><td colspan="2">Monitoring, modelling and forecasting systems</td></tr>
</table>

Vulnerability Reduction · *Disaster Risk Reduction* · *Socio-Ecological Resilience* · *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

11.7.1.2. Maritime transport

The Sicilian maritime transport sector adaptation pathways are characterized by a significant heterogeneity across the four potential Adaptation Policy Trajectories (APTs). In general, a certain combination of investment and commitment, then a certain level of concrete involvement emerge for this sector.

As in the tourism sector, the most selected option for maritime transport is in the class of the Social-Ecological Resilience and it is considered the best for all the timeframes and with a combination of medium investment and commitment (APT B and C). For this class, there is a certain availability in investment for the medium and long term, mainly concerning the coastal protection, which represent a priority also in respect of alternative and sustainable propulsions for ships. These ones are selected as long-term option in APT B and C. Ocean pools are not considered a measure to implement in Sicily. The orientation is toward the improvement of the infrastructures with medium long-term strategies and investments.

In the context of Risk Reduction class of adaptation, the selection of the different measures is different both in terms of timeframes and in terms of combination among investments and commitment. The most selected measures concern the creation of an Intelligent transport system but in APT A, then with low investment and low commitment. The other options are the post disaster recovery (APT A low investment and commitment) to react to the impacts and the prevention systems to avoid negative effects (APT C – low investments and medium commitment). The two risk mitigation options are considered equally desirable. Preparing for service delays or cancellations, instead, is not considered as a priority and could be a strategy only in the short time under APT C and D.

For the Vulnerability Reduction, among the financial instruments available, the insurance mechanisms fit well in the mid and long term, while the financial incentives are considered useful in the short term, in APT B and D (see **Table 11.8**).

Table 11.8. Proposed adaptation options for maritime transport in Sicily.

Pathway	Short-term (up to 2030)	Mid-century (up to 2050)	End-of-century (up to 2100)
APT A – Pathway — **Minimum Intervention** low investment, low commitment to policy change — This policy trajectory assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts	Awareness campaigns for behavioural change		Social dialogue for training in the port sector
	Climate proof ports and port activities		Consider expansion/retreat of ports in urban planning
	Intelligent Transport Systems (ITS)		Prepare for delays or cancellations
	Backup routes and infrastructures during extreme weather		Post-disaster recovery funds
	Marine life friendly coastal protection structures	Combined protection and wave energy infrastructures	
APT B – Pathway — **Economic Capacity Expansion** high investment, low commitment to policy change — This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy	**Short-term (up to 2030)**	**Mid-century (up to 2050)**	**End-of-century (up to 2100)**
	Financial incentives to retreat from high-risk areas		Insurance mechanisms for ports
	Awareness campaigns for behavioural change	Social dialogue for training in the port sector	
	Sturdiness improvement of vessels	Increase operational speed and flexibility in ports	
	Consider expansion/retreat of ports in urban planning		Climate proof ports and port activities
	Marine life friendly coastal protection structures	Combined protection and wave energy infrastructures	
	Coastal protection structures	Hybrid and full electric ship propulsion	
APT C – Pathway — **Efficiency Enhancement** medium investment, medium commitment to policy change — This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system	**Short-term (up to 2030)**	**Mid-century (up to 2050)**	**End-of-century (up to 2100)**
	Awareness campaigns for behavioural change	Social dialogue for training in the port sector	
	Climate resilient economy and jobs	Diversification of trade using climate resilient commodities	
	Restrict development and settlement in low-lying areas	Refrigeration, cooling and ventilation systems	
	Climate proof ports and port activities	Consider expansion/retreat of ports in urban planning	
	Reinforcement of inspection, repair and maintenance of infrastructures	Early Warning Systems (EWS) and climate change monitoring	
	Marine life friendly coastal protection structures		Combined protection and wave energy infrastructures
	Coastal protection structures		Hybrid and full electric ship propulsion
	Integrate ports in urban tissue		
APT D – Pathway — **System Restructuring** high investment, high commitment to policy change — This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems	**Short-term (up to 2030)**	**Mid-century (up to 2050)**	**End-of-century (up to 2100)**
	Financial incentives to retreat from high-risk areas	Insurance mechanisms for ports	
	Awareness campaigns for behavioural change	Social dialogue for training in the port sector	
	Restrict development and settlement in low-lying areas	Refrigeration, cooling and ventilation systems	
	Consider expansion/retreat of ports in urban planning	Climate proof ports and port activities	
	Post-disaster recovery funds	Backup routes and infrastructures during extreme weather	Post-disaster recovery funds
	Marine life friendly coastal protection structures	Combined protection and wave energy infrastructures	

Vulnerability Reduction · *Disaster Risk Reduction* · *Socio-Ecological Resilience* · *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

11.7.1.3. Energy

In general, the energy sector in Sicily is characterized by heterogeneity concerning the selection of adaptation options in all Adaptation Policy Trajectories (APTs). APT C is the prevailing combination of investment and commitment, highlighting as there is a wide awareness about the need to do something concretely improving the medium and long-term scenarios.

Across all ATPs, for vulnerability reduction, pathways mainly rely on energy storage and green jobs. Both options are considered at least for the mid and long-term. In contrast, public information on climate action (also human capital; APT B and C) is not a priority, since it is assumed that there is and will be a sufficient level of public information in the island for it to pursue climate action. In the same way, the collection of forest fuel loads is part of pathways D for the short term, but it relies as the last option. Moreover, the financial capital is considered necessary, almost with equal intensity, and with a certain combination of investment and commitment, in APT B and D.

For Disaster Risk Reduction, the grid reliability is the most selected option in APT C for the mid and long term. On the opposite, the early warning system is not a priority, chosen only in APT C as a short-term measure. The options within the classes risk mitigation, disaster response and Post-disaster recovery have the same distribution of preference. Particularly, the options with the higher percentage (56%) are valid for the short and the long term, instead the remaining ones are chosen for the medium timeframe. Moreover, reviewed building codes and generators are present in all the APTs for all the timeframes.

Regarding Social-Ecological Resilience, heated pools with waste heat from power plants is considered a priority in all the timeframes of APT C. Except for underground tubes and piping in urban planning, chosen for all the APTs, the other measures are characterized by a certain degree of investment and commitment (APT B and C). The options in the regulating and maintenance services class are considered equally relevant and with the same degree of priority. The educational gardens are not a priority, then it seems that there is enough awareness and knowledge about climate implication in the energy sector (see **Table 11.9**).

Table 11.9. Proposed adaptation options for the energy sector in Sicily.

Pathway	Short-term (up to 2030)	Mid-century (up to 2050)	End-of-century (up to 2100)
APT A – Pathway — **Minimum Intervention** low investment, low commitment to policy change — This policy trajectory assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts	Green jobs and businesses		
	Review building codes of the energy infrastructure	Upgrade evaporative cooling systems	Review building codes of the energy infrastructure
	Study and develop energy grid connections	Energy-independent facilities (generators)	Study and develop energy grid connections
	Energy recovery microgrids		
	Underground tubes and piping in urban planning		Energy efficiency in urban water management
APT B – Pathway — **Economic Capacity Expansion** high investment, low commitment to policy change — This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy	**Short-term (up to 2030)**	**Mid-century (up to 2050)**	**End-of-century (up to 2100)**
	Financial support for smart control of energy in houses and buildings	Financial support for buildings with low energy needs	
	Public information service on climate action	Green jobs and businesses	
	Demand Side Management (DSM) of Energy	Seawater Air Conditioning (SWAC)	Demand Side Management (DSM) of Energy
	Review building codes of the energy infrastructure	Upgrade evaporative cooling systems	Review building codes of the energy infrastructure
	Energy efficiency in urban water management	Underground tubes and piping in urban planning	
	Biomass power from household waste	Urban green corridors	
APT C – Pathway — **Efficiency Enhancement** medium investment, medium commitment to policy change — This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system	**Short-term (up to 2030)**	**Mid-century (up to 2050)**	**End-of-century (up to 2100)**
	Public information service on climate action	Green jobs and businesses	
	Small scale production and consumption (prosumers)		
	Energy storage systems		
	Review building codes of the energy infrastructure	Upgrade evaporative cooling systems	Review building codes of the energy infrastructure
	Early Warning Systems (EWS)	Grid reliability	
	Energy efficiency in urban water management	Underground tubes and piping in urban planning	
	Biomass power from household waste	Urban green corridors	
	Heated pools with waste heat from power plant		

Table 11.9 (Cont.). Proposed adaptation options for the energy sector in Sicily.

APT D – Pathway	Short-term (up to 2030)	Mid-century (up to 2050)	End-of-century (up to 2100)
System Restructuring high investment, high commitment to policy change — This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems	Financial support for smart control of energy in houses and buildings	Financial support for buildings with low energy needs	Financial support for smart control of energy in houses and buildings.
	Green jobs and businesses		
	Collection and storage of forest fuel loads	Energy storage systems	
	Review building codes of the energy infrastructure	Upgrade evaporative cooling systems	
	Local recovery energy outage capacity		Energy recovery microgrids
	Energy efficiency in urban water management		Underground tubes and piping in urban planning

Vulnerability Reduction | *Disaster Risk Reduction* | *Socio-Ecological Resilience* | *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

11.7.1.4. Aquaculture

In general, the aquaculture sector in Sicily is characterized by a heterogeneous selection of adaptation options in all Adaptation Policy Trajectories (APTs). APT A prevails in Disaster Risk Reduction class of adaptation and APT B and C are the prevalent choice in Social Ecological Resilience measures, while the Vulnerability Reduction is characterized by a certain combination of APT B, C and D. This shows the degree of commitment and investment associated to each class.

The most selected measures concern vulnerability reduction, that is recirculation aquaculture systems and integrated multi-trophic aquaculture. These options are selected for all the timeframes respectively in APT B for the first one and APT C and D for the other one. Since they are perceived as urgent, there is a certain degree of investment and commitment towards them. The measures concerning human and social capital are selected for all the ATPs and different timeframes and show the same share of preference within each class.

For Disaster Risk Reduction, the monitoring and the implementation of a warning plan are considered a priority option, showing that the prevention measures and tools are fundamental. All the measures included in this category of class of adaptation have a certain level of relevance for local experts, so they are in all the APTs and in all the timeframes.

Regarding Social-Ecological Resilience, the measures with the higher score are considered for all the timeframes within the single ATP in which they are selected. Promote aquaculture and better management practices consider a different combination of investment and commitment (ATP B and C), but they are considered valid in the short, medium, and long term. The feed production is the option universally selected for all the ATPs and timeframes. In this field, the need for measure addressing different aspect emerges (see **Table 11.10**).

Table 11.10. Proposed adaptation options for aquaculture in Sicily.

APT A – Pathway	Short-term (up to 2030)	Mid-century (up to 2050)	End-of-century (up to 2100)
Minimum Intervention low investment, low commitment to policy change — This policy trajectory assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts	Awareness campaigns for behavioural change	Efficient feed management	
	Climate proof aquaculture activities		Risk-based zoning and site selection
	Mainstreaming Disaster Risk Management	Contingency for emergency management, early harvest and/or relocation	
	Recovery Post-disaster plans		
	Species selection	Feed production	

Table 11.10 (Cont.). Proposed adaptation options for aquaculture in Sicily.

Pathway	Short-term (up to 2030)	Mid-century (up to 2050)	End-of-century (up to 2100)
APT B – Pathway — **Economic Capacity Expansion** high investment, low commitment to policy change — This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy	Tax benefits and subsidies		Financial schemes, insurance and loans
	Awareness campaigns for behavioural change		Efficient feed management
	Recirculation Aquaculture Systems (RAS)	Submersible cages	Recirculation Aquaculture Systems (RAS)
	Climate proof aquaculture activities	Risk-based zoning and site selection	
	Species selection	Feed production	
	Selective breeding	Best Management Practices	
APT C – Pathway — **Efficiency Enhancement** medium investment, medium commitment to policy change — This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system	**Short-term (up to 2030)**	**Mid-century (up to 2050)**	**End-of-century (up to 2100)**
	Awareness campaigns for behavioural change	Efficient feed management	
	Addressing consumer and environmental concerns at the local level	Promote cooperation to local consumption	
	Integrated multi-trophic aquaculture		
	Climate proof aquaculture activities	Risk-based zoning and site selection	
	Environmental monitoring Early Warning Systems (EWS)	Disease prevention methods	Environmental monitoring Early Warning Systems (EWS)
	Species selection	Feed production	
	Selective breeding	Best Management Practices	
	Create educational visits	Promote aquaculture cuisine	
APT D – Pathway — **System Restructuring** high investment, high commitment to policy change — This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems	**Short-term (up to 2030)**	**Mid-century (up to 2050)**	**End-of-century (up to 2100)**
	Tax benefits and subsidies	Financial schemes, insurance and loans	
	Awareness campaigns for behavioural change	Efficient feed management	
	Integrated multi-trophic aquaculture		Short-cycle aquaculture
	Climate proof aquaculture activities	Risk-based zoning and site selection	
	Recovery Post-disaster plans		Recovery post-disaster funds
	Feed production	Species selection	Feed production

- *Vulnerability Reduction*
- *Disaster Risk Reduction*
- *Socio-Ecological Resilience*
- *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

Chapter

12

West Indies

SOCLIMPACT

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 776661

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French West Indies at a Glance

The French West Indies refers to the Overseas department and the archipelago of Guadeloupe and the territorial collectivity of Martinique, both located in the Lesser Antilles. Guadeloupe has a total surface area of 1,628 km² and a population of 395,000 inhabitants. On the other hand, Martinique has a surface area of 1,128 km² and a population of 375,000 inhabitants. The economy of both islands heavily depends on tourism and agriculture export as a source of foreign exchange. They are reliant upon mainland France for product import.

The Blue Economy Sectors

- **Aquaculture**

  Marine aquaculture in Guadeloupe and Martinique has 2 companies that breed only the Caribbean Wolf (Sciaenops ocellata). Production is low (35 tonnes in 2019 in Martinique), because the operators are small family units. This sector of activity faces several economic (competition with imports, food prices), health (pollution, viruses) and technical difficulties (sargassum, cyclone). To revitalize the sector, research is currently underway to identify a new species adapted to farming conditions with good growth potential.

- **Maritime Transport**

  The large seaport of Guadeloupe brings together several activities ranging from the traffic of goods to that of passengers. 90 % of the goods go through the Jarry site. Like Guadeloupe, Martinique's large seaport, located in the bay of Fort-de-France, brings together several specialized sites. It concentrates 98 % of merchandise traffic and allows the transport of passengers and cruise passengers.

- **Energy**

  Fossil energy accounts for 76.5 % of Martinique's energy mix. The share of renewable energy is steadily increasing and is currently made up of photovoltaic (13.3 %), biomass (6.7 %) and wind power (2.4 %). Overall, consumption amounts to 1526 GWh. In Guadeloupe, electricity consumption amounts to 1465 GWh. 21.4 % concerns renewable energies, mainly geothermal energy, followed by photovoltaic, biomass, wind and hydraulic power. The two islands appear far from the goals set by the government for 2030, but have some potential to develop new sources of renewable energy.

- **Tourism**

  In 2019, tourism accounted for 9.5 % of Guadeloupe's GDP. The high season for both islands runs from November to April. In recent years, strong growth has been observed in the sector thanks to cruise tourism. It is mainly the landscape and beaches that attract tourists in Martinique and Guadeloupe. The majority come from mainland France, other European countries, but also from the United States.

12.1. Current Climate and Risks

There are two main seasons in the French West Indies. Average temperatures experience little variation during the year, between 2 and 4 degrees, depending on the time of day and location. The average rainfall is mainly related to the relief. The dry season, also called “Carême”, lasts from February to April and is characterised by temperatures that can reach between 28 and 30 degrees during the day. It is also the sunniest period of the year. The other season, wet season, lasts from June to October and is very hot and humid. The Intertropical Convergence Zone is getting closer to the West Indies. The rains are more numerous and intense. Maximum temperatures can reach between 32 °C. This season is also associated with cyclones. The wind called trade winds blows almost permanently from East to North-East between 30 and 50 km/h but is weaker and irregular during this season (see **Figure 12.1** and **Figure 12.2**).

CURRENT CLIMATE-RELATED RISKS

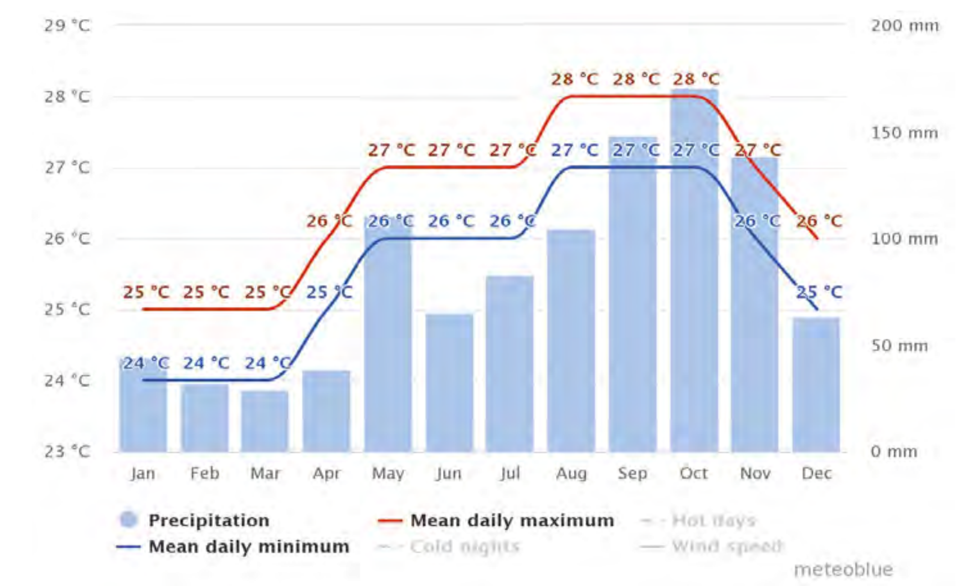
- Coastal flood High
- Cyclone High
- Urban flood Medium
- Extreme heat Medium

SIGNIFICANT CLIMATE EVENTS

- Hurricane (2017: Irma, Maria and José)
- Intense rainfall, floods (2017)

CLIMATE CHARACTERISTICS (16.26°N 61.56°W, 5m asl)

Average temperature and precipitation



Wind speed

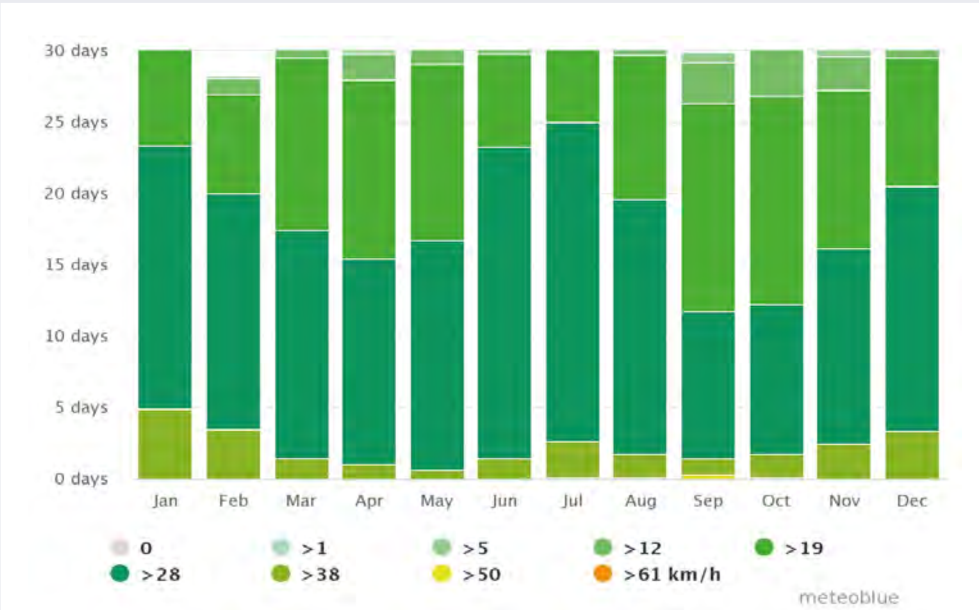
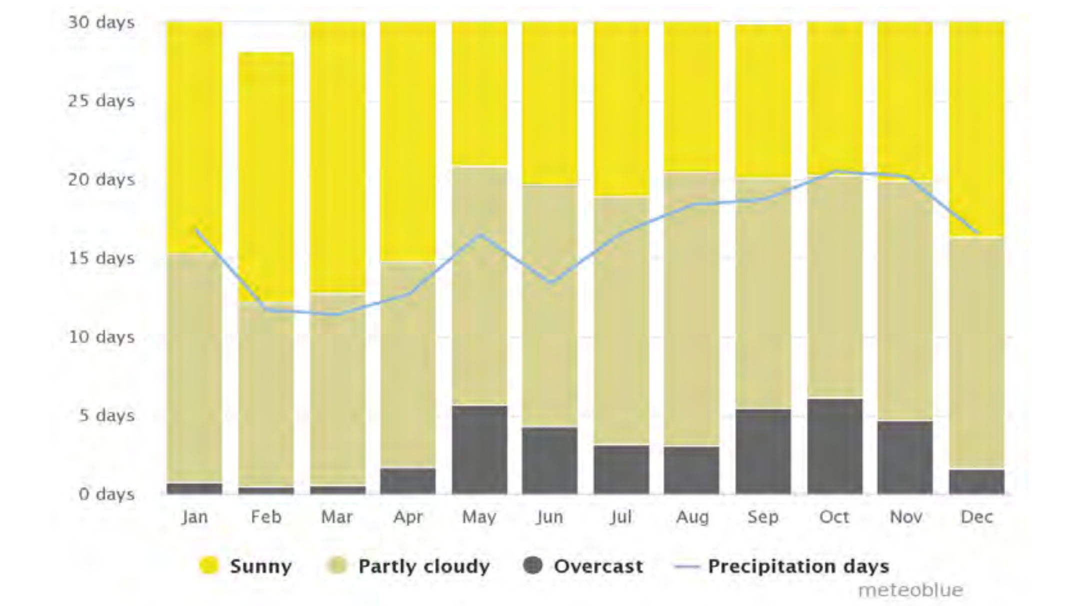


Figure 12.1. Climate factsheets of Martinique.

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System). **(Continued on the next page)**

Cloudy, sunny and precipitation



Wind rose

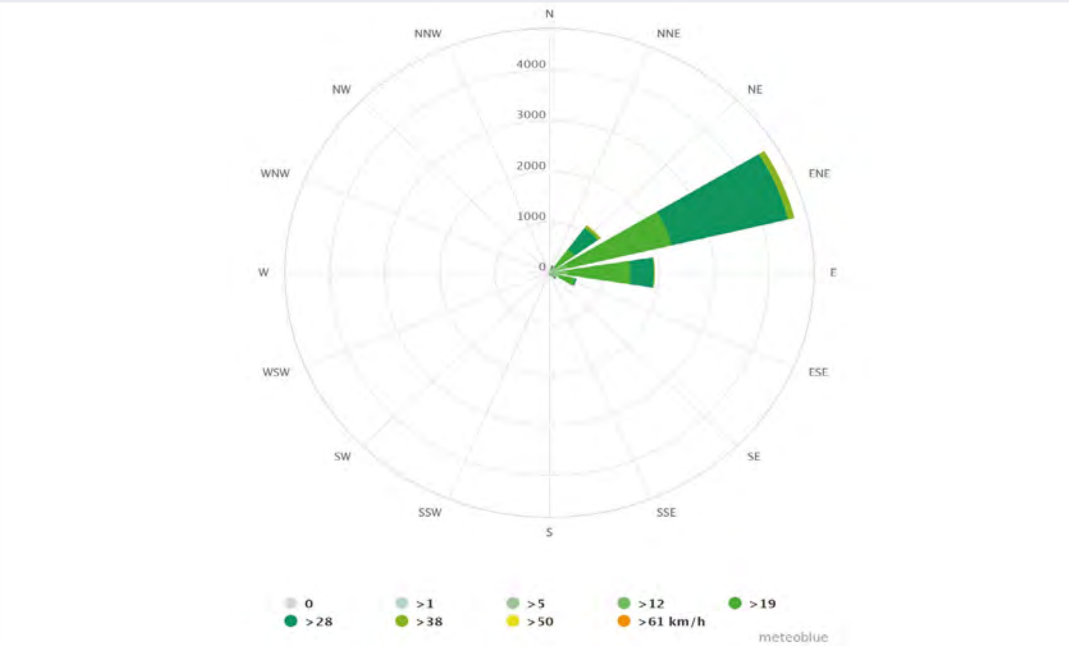


Figure 12.1 (Cont.). Climate factsheets of Martinique.

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System).

CURRENT CLIMATE-RELATED RISKS

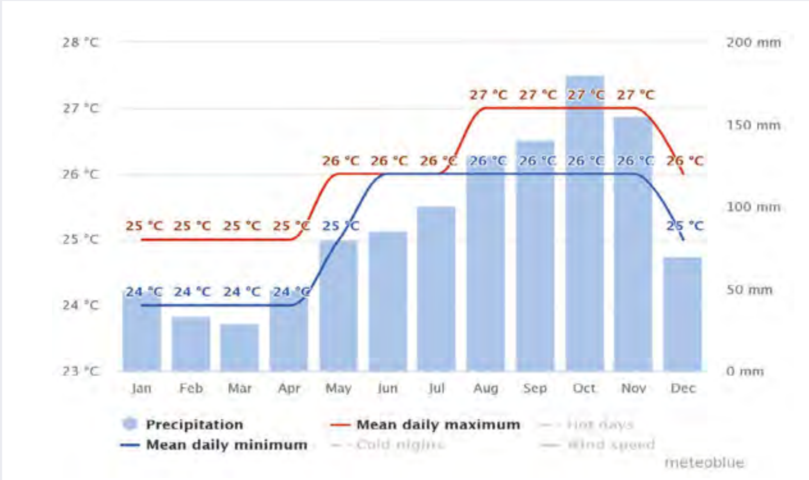
- Urban flood High
- Coastal flood High
- Cyclone High
- Extreme heat Medium

SIGNIFICANT CLIMATE EVENTS

- Hurricane (2017: Irma, Maria and José)
- Intense rainfall, floods (2017)

CLIMATE CHARACTERISTICS (14.66°N 61°W, 114m asl)

Average temperature and precipitation



Wind speed

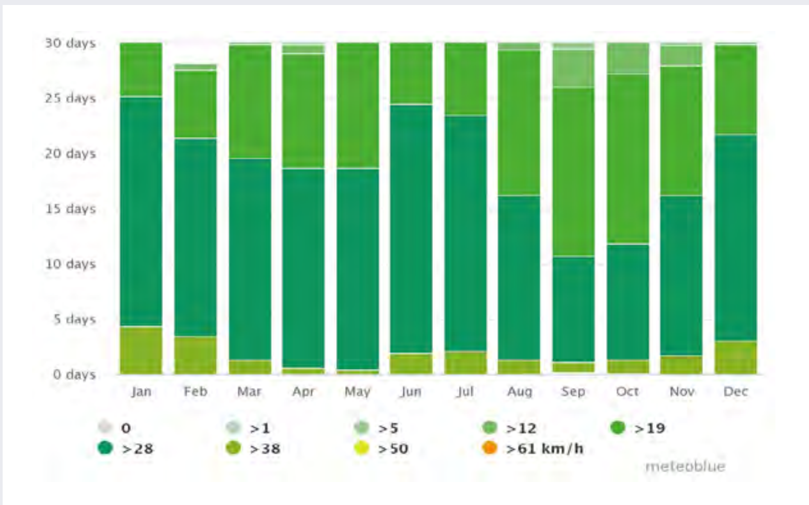
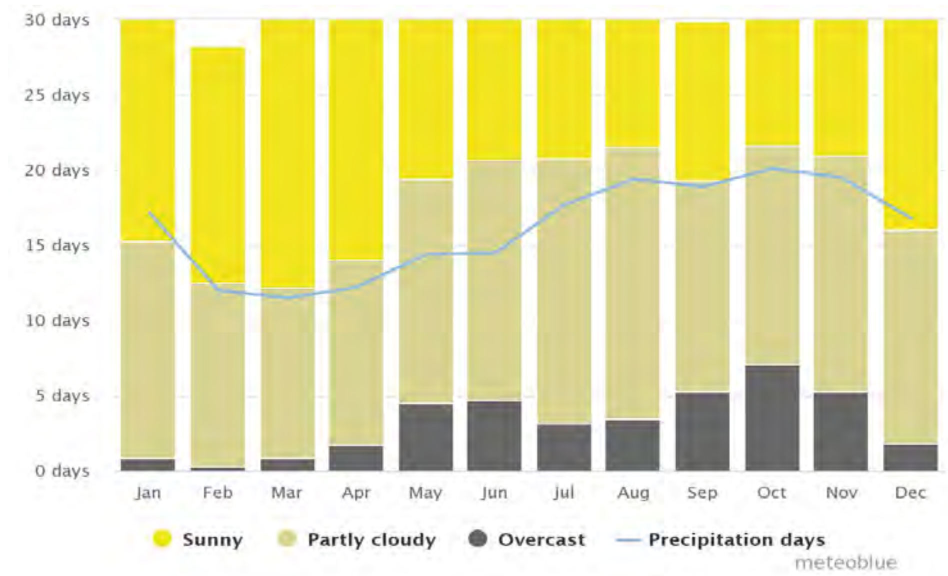


Figure 12.2. Climate factsheets of Guadeloupe.

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System). ***(Continued on the next page)***

Cloudy, sunny and precipitation



Wind rose

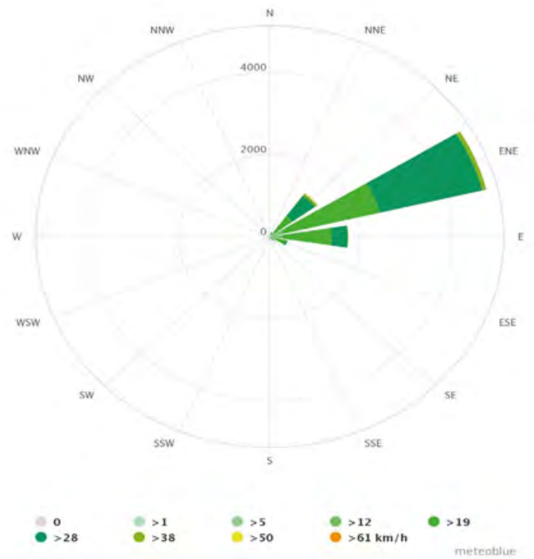


Figure 12.2 (Cont.). Climate factsheets of Guadeloupe.

Source: Own elaboration with data from GFDRR ThinkHazard!; D7.1. Conceptual Framework and Meteoblue; Meteoblue global NEMS (NOAA Environmental Modeling System).

12.2. Climate Change Outlook

Climate hazards indicators represent the entry point to understand the climate change exposure of the blue economy sectors. The indicators have been computed for two scenarios, RCP2.6 (low emission scenario) and RCP8.5 (high emission scenario) and for different horizon times namely: a reference period (1965-2005), mid-century (2046-2065) and end of century (2081-2100).

As to its reliability, it is important to note that Atlantic islands (Azores, Madeira, Canaries and West Indies) lie in very critical areas where global models might be inaccurate in predicting the large scale patterns (regional models are not available), and resolution is so coarse that in fact many islands don't even exist in model orography. This acknowledged, this is the only information we can provide, and at least future tendencies can be inferred. The new CMIP6 simulations might shed more light on this issues, but we can only suggest that results should be updated as they become available.

The same partly holds for the wave simulations: local resolution has been significantly increased in the dedicated new simulations of this project, performed by the partner ENEA (up to 0.05°), but the forcing wind field is still derived from the coarse global models.

Stakeholders should be made aware that uncertainty is an inherent characteristic of climate data, and that any future planning must cope with it. Climatologists can only highlight potential threats and constraints, they cannot predict the future and pave the way to solutions. Conveying this piece of information is one of the most critical points of climate change related information.

12.2.1. Tourism

12.2.1.1. Beach flooding and related losses

One of the consequences of an increase in the mean sea level will be the flooding of coastal areas. This includes sand beaches, which are the main asset for tourism activities in most of the European islands. Therefore, estimating the potential risk of beach loss due to climate change is of paramount importance for the economy of those islands.

The 95th percentile of the flood level averaged was selected as an indicator of interest. The values are presented as anomalies with respect to the present mean sea level at beach location (i.e., including the median contribution of runup).

In all cases, an increase is expected being larger at the end of the century under scenario RCP8.5. The values in that scenario is 131.37 cm in West Indies (see **Figure 12.3** and **Table 12.1**).

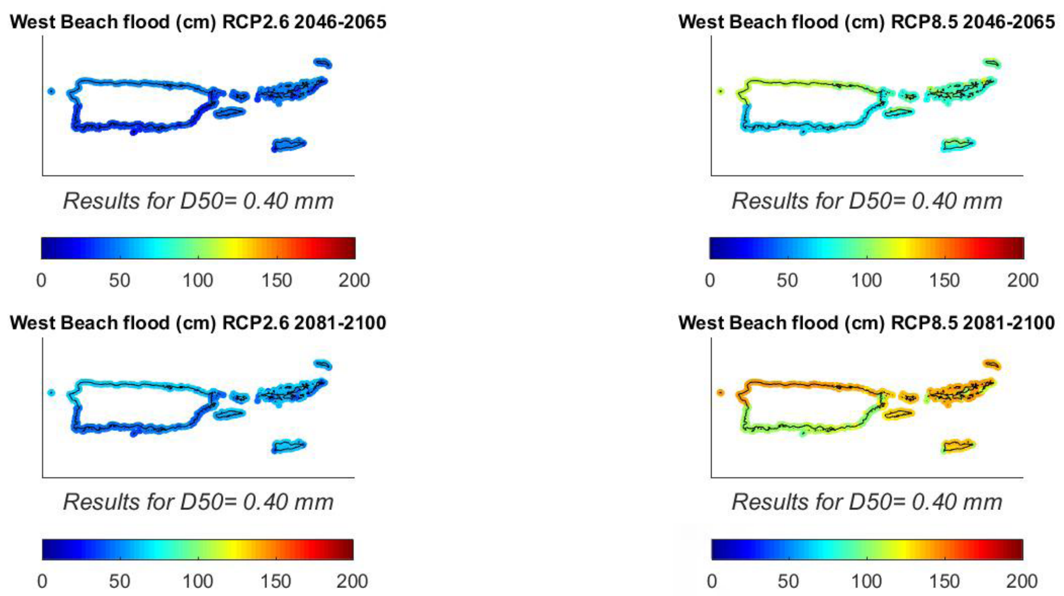


Figure 12.3. Projected extreme flood level (in the vertical, in cm) at beach locations with respect to the present (1986-2005) mean sea level values averaged for the islands under scenario RCP2.6 (left) and RCP8.5 (right). Own elaboration based on global and regional simulations.

Source: SOCLIMPACT Deliverable Report - D4.4d. Report on the evolution of beaches.

Table 12.1. Projected extreme flood level (in the vertical) at beach locations with respect to the present (1986-2005) mean sea level values averaged for the island. Ensemble of models using global simulations produced by Hemer *et al.* (2013).

Low emission scenario (RCP 2.6)	Low emission scenario (RCP 2.6)	High emission scenario (RCP8.5)	High emission scenario (RCP8.5)
Mid-Century (2046-2065)	End of Century (2081-2100)	Mid-Century (2046-2065)	End of Century (2081-2100)
Absolute value	**Absolute value**	**Absolute value**	**Absolute value**
45.11 cm	57.35 cm	87.61 cm	1.37 cm

Source: SOCLIMPACT Deliverable Report - D4.4d Report on the evolution of beaches.

Under mean conditions, we find that, at end of century, the total beach surface loss range from ~46% under scenario RCP2.6 to ~77% under scenario RCP8.5 (see **Figure 12.4**).

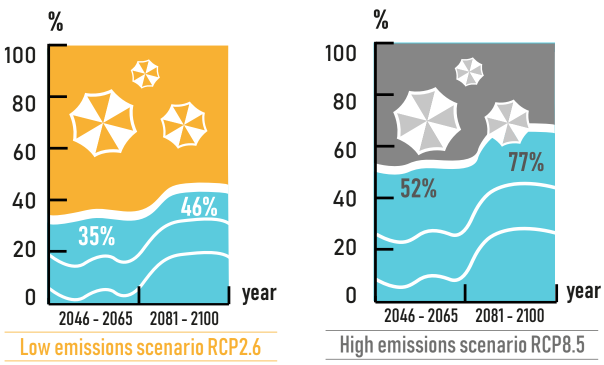


Figure 12.4. Beach reduction% (scaling approximation).

Source: SOCLIMPACT Deliverable Report - D4.4d. Report on the evolution of beaches.

12.2.2. Maritime Transport

12.2.2.1. Sea Level Rise (SLR)

Sea Level Rise (SLR) is one of the major threats linked to climate change. It would induce permanent flooding of coastal areas with a profound impact on society, economy and environment. Moreover, an increase in the mean sea level would result in a larger impact of coastal storms with the consequent increase of risk. The results are presented in terms of mean sea level rise. For West Indies, the SLR ranges from 26.91 cm (RCP2.6) to 70.27 cm (RCP8.5) at the end of the century (see **Figure 12.5**).

12.2.2.2. Wave extremes (99th percentile of significant wave height averaged)

Marine storms can have a negative impact on maritime transport, coastal-based tourism and aquaculture, among other activities. To illustrate this impact, the 99th percentile of significant wave height averaged has been chosen. A decrease in the extreme wave height is found being larger under scenario RCP8.5 as illustrated in the following map and table in far future (-5%) (see **Figure 12.6**).

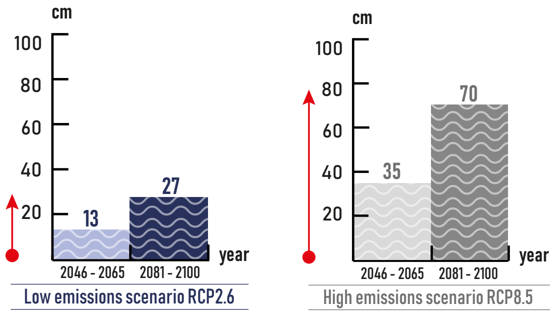


Figure 12.5. Mean sea level rise (in cm) with respect to the reference period (1986-2005). Own elaboration based on global and regional simulations.

Source: SOCLIMPACT Deliverable Report - D4.4b. Report on storm surge levels.

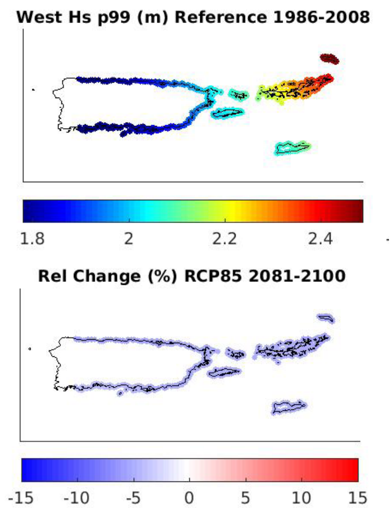


Figure 12.6. The 99th percentile of significant wave height averaged for the reference period and the relative change for the RCP8.5. Own elaboration based on global and regional simulations. *Source: SOCLIMPACT Deliverable Report - D4.4b. Report on storm surge levels.*

12.3. Risk Assessment

12.3.1. Tourism

For the tourism sector, three impact chains (IC) were operationalized:

- Loss of attractiveness of a destination due to the loss of services from marine ecosystems.
- Loss of comfort due to increase of thermal stress.
- Risk of forest fires and loss of attractiveness.

For the first two, the AHP method was employed. This methodology is ideal to respond to the hierarchical nature of the impact chain and, secondly, for using expert judgements to assess the comparative risk for the islands over a large number of indicators. By the side of shadows, this method requires quite specific data that was not able to collect for some islands. The AHP method also requires "values" for experts to compare.

More specifically, for the first IC the data is needed for "Tourist Arrivals" and "Vulnerable Groups" indicators, which is regards the exposure of people to heatwaves for the hottest period, such as:

- Number of tourist arrivals per month for the past 5 years.
- Number of tourists per month aged 14 and under for the past 5 years.
- Number of tourists per month aged 65 and over for the past 5 years.
- Percentage of tourist activities that are sensitive to heatwaves (such as hiking, etc.).
- Number of beds available in medical facilities per 100,000 inhabitants.

If, for example, an island gets a lot of tourists, but most of them just spend their time by the beach, then the island is not so much at risk of losing tourists because when they visit, they'll be by the beach and able to cool down. On the other hand, if almost all tourists visit the island for hiking, but it gets too hot, then the island could be at risk since some may change their minds and visit somewhere else with a moderate climate and do their hiking there. Additionally, it is necessary to investigate how well an island is equipped to deal with patients who suffer from a heatwave-related episode.

For the second IC, the data collected was:

- Surface of marine phanerogams & phanerogams' reduction due to heat: surface in km^2, and expected% of surface loss for RCP8.5 distant future.
- Number of divers: number of tourists practising diving at the destination.
- Products substitution capacity: capacity to derive tourist demand to non-marine habitat-based activities.
- Seagrass removal: capacity to remove dead seagrass lying on beaches.
- Sea water pollution: quality of management of inshore and offshore sewages.

If one information is missing, it is not possible to conduct the risk assessment analysis, as it is a comparative analysis between European islands.

Finally, the GIZ method utilized for the operationalization of the third IC did not require experts evaluation, although the type of data utilized was also quite specific, regarding environmental, socio-economic, and spatial planning data (e.g., land use and cover). In some cases, local stakeholders and authorities were reached by the partners of the project. In other cases, partners provided an additional effort searching for and collecting data for the successful operationalization of the impact chains. Finally, the data were checked in order to verify similar coverage and timeframes. The West Indies show insufficient data availability.

The data with more difficulties to be collected were:

- Cultivated area (Pcrops).
- Forest in a protected area.
- Tourist density.
- Flammability index.
- Density of firefighters and voluntary.
- Fires risk plan.

12.3.2. Aquaculture

In our study, aquaculture includes only marine-based operations where off-shore and coastal aquaculture are included, and freshwater and land-based aquaculture are excluded. Examples of climate change hazards that can impact aquaculture are changes in ocean warming and acidification, as well as oceoanographic changes in currents, waves, and wind speed. Sudden impacts such as an increase in the frequency and intensity of storms and heat waves are also impacting aquaculture. Other effects of climate change on aquaculture activities are increased invasions from alien species, increased spread of diseases and changes in the physiology of the cultivated species by changing temperature, oxygen availability and other important physical water parameters. An important indirect impact to aquaculture is the change in fisheries production due to climate change. Aquaculture of finfish is highly dependent on fisheries for feed ingredients. This is already a current problem with many fisheries overexploited and will only intensify in the future. Climate change is also predicted to impact food safety, where temperature changes modify food safety risks associated with food production, storage, and distribution.

Socio-economic impacts on aquaculture are hard to assess due to the uncertainty of the changes in hazards and the limited knowledge these impacts have on the biophysical system of aquaculture species (Handisyde *et al.*, 2014). Thus, the following risks were studied:

1) Risk of fish species thermal stress due to increased sea surface temperature.

   Changes in water temperature can directly affect the growth rate and Feed Conversion Ratio of the fish. Temperature also affects the oxygen levels and can cause harmful algae blooms, reduce water quality and an increase in occurrence of diseases and parasites which can affect the fish or other culture species. A change in temperature can ultimately change the ranges of suitable species for a certain area but can also have positive impacts such as increased growth (mainly in tropical and sub-tropical regions) and a longer growing season. Primary productivity can also increase with increasing temperature, which may be beneficial for filter feeders such as mussels.

2) Risk of increased fragility of the aquaculture activity due to an increase of extreme weather.

   Increased frequency and intensity of extreme weather events result in higher waves and storm surges and changes in salinity. These events result in loss of stock and damages to infrastructure and require adaptation in species selection, site selection and technologies.

Indeed, the objective of the risk assessment is to obtain final risk scores according to a gradient (very low to high) and to be able to compare the European islands with each other. For West Indies, it was difficult to obtain the adequate data to make these comparisons. The type of data that was necessary to compile was:

- Farm area (km^2).
- Value of stocks.
- Quick support intervention plans.
- Early warning system.
- Sensivity of species.

12.3.3. Energy

There are more than 2200 inhabited islands in the EU. Lately, they have come into the focus of the EU, which addresses energy questions as part of the 'clean energy for all Europeans' package. The clean energy for EU islands initiative provides a long-term framework to help islands generate their own sustainable, low-cost energy. This is particularly interesting because many islands have vast amounts of renewable energy sources but rely on fossil fuel imports yet. These are relevant challenges regarding the energy transition in the EU, whose aim of net zero greenhouse gas emissions in 2050 should determine the future energy plans of the islands, so they could provide showcases for successful 100% renewable energy supply.

Most Renewable Energy Systems (RES) depend on the climate, and therefore, climate change can have an impact of the resource amount. Additionally, wind and solar PV energy are not dispatchable, and its variability represents a challenge for its integration in the power system. This is a challenge that can be addressed through storage or backup plants (which can be itself renewable energy plants), through demand management, but also taking advantage of complementarity of PV and wind energy and its very different variability characteristics.

There are also challenges for the demand and transmission components of the energy systems of the islands due to climate change: changes in temperature leading to changing energy demand, changes in precipitation and evaporation creating risks for desalination, and extreme weather events (particularly extreme winds) challenging the distribution infrastructure. After intensive desk research, the latter was ruled out due to the low number of past incidents found in the literature or news media and the future projections showing a reduction in wind extremes for most islands.

Thus, for the energy sector three general impact chains (IC) have been developed:

- Risk of changes in power generation due to long term climate change and variability.
- Risk of changes in energy demand due to changes in precipitation and temperatures.
- Risk of damages to transmission grids due to extreme events.

Only the second IC was selected for operationalization. Data availability constraints for all islands have been a basic reason for this selection. For this IC, two different analysis were carried out:

- The increased energy demand due to increased cooling demand.
- The increased energy demand due to increased desalination needs.
- Both risks depend on the temperature increase, which is a very certain effect of climate change.

The criteria for the selection of the islands have been: (a) availability of data for the computation of the exposure and vulnerability indicators of the demand-side ICs, (b) modeling constraints of the hazard component. In both cases, West Indies show a lack of reliable and updated data.

12.3.4. Maritime Transport

For the maritime transport sector, three main climate change risks have been identified. These are: i) risk of damages to ports' infrastructures and equipment due to floods and waves, ii) risk of damages to ships on route (open water and near coast) due to extreme weather events, and iii) risk of isolation due to transport disruption.

The operationalization was applied to the third one (risk of isolation due to transport disruption), which in terms of hazards and impacts can be considered as a combination of the other two. The selection of islands to be included in the analysis was based on the importance and dependency on the maritime transport sector and on data availability.

Although this sector is of great importance for the economy of West Indies, the lack of reliable and consistent data limited the analysis, especially in regard to:

- Value of transported goods expressed in freight (VGTStot.)
- Number of renovated infrastructure (NAgePo).
- Percentage of renewables (PEnRR).
- Early warning systems (NOcSta) and harbour alternatives (NApt).

Nevertheless, this information is also useful at the moment of evaluating and ranking adaptation measures for the islands.

12.4. Impacts on the Blue Economy Sectors

12.4.1. Tourism (Non-Market Analysis)

In order to analyse the reactions of tourists to the impacts of climate change and the preferences for adaptation policies, several hypothetical situations were posed to 200 tourists visiting the West Indies, whereby possible climate change impacts were outlined for the island (i.e., beach erosion, infectious diseases, forest fires, marine biodiversity loss, heat waves, etc.) (see **Figure 12.7**).

Firstly, tourists had to indicate whether they would keep their plans to stay on the island or find an alternate destination if the impact had occurred, which allows predictions of the effects on tourism arrivals to be made for each island. Secondly, tourists were asked to choose between various policy measures funded through an additional payment per day of stay – the tourists' choices being an expression of their preferences for attributes/policies. To estimate the results, the conditional logit model was run by using the Stata software.

In general, data confirms that tourists are highly averse to risks of infectious diseases becoming more widespread (55.50 % of tourists would change destination). Moreover, they are not willing to visit islands where beaches largely disappear (38 %) or where water is scarce for leisure activities (34.50 %). In addition, policies related to beaches protection (9.2 €/day), land habitats restoration (19.1 €/day), and the prevention of infectious diseases (7.9 €/day) are the most valued, on average, by tourists visiting these islands.

Although climate change impacts are outside the control of tourism practitioners and policy-makers, they can nevertheless utilise this knowledge to improve the predictability of the effect of certain adaptation policies and risk management strategies, and develop their plans accordingly (see **Figure 12.8**).

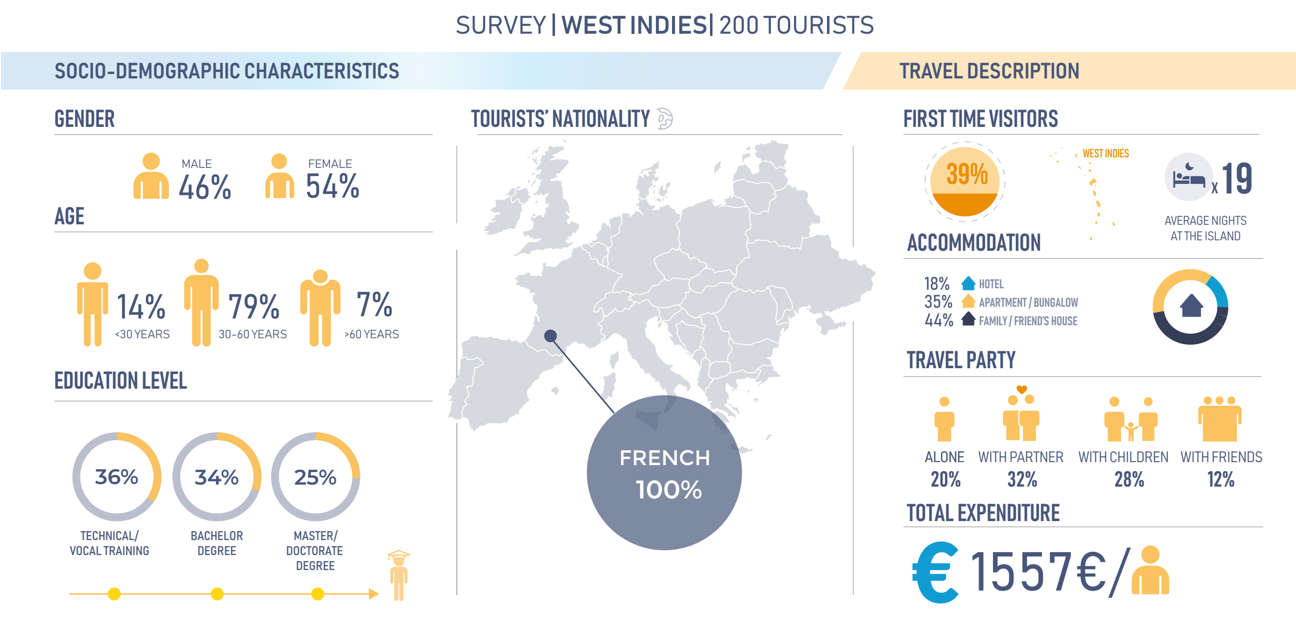


Figure 12.7. Socio-economic characteristics and travel description: tourists visiting West Indies.

Source: SOCLIMPACT Deliverable Report D5.5. Report on market and non-market costs of Climate Change and benefits of climate actions for Europe.

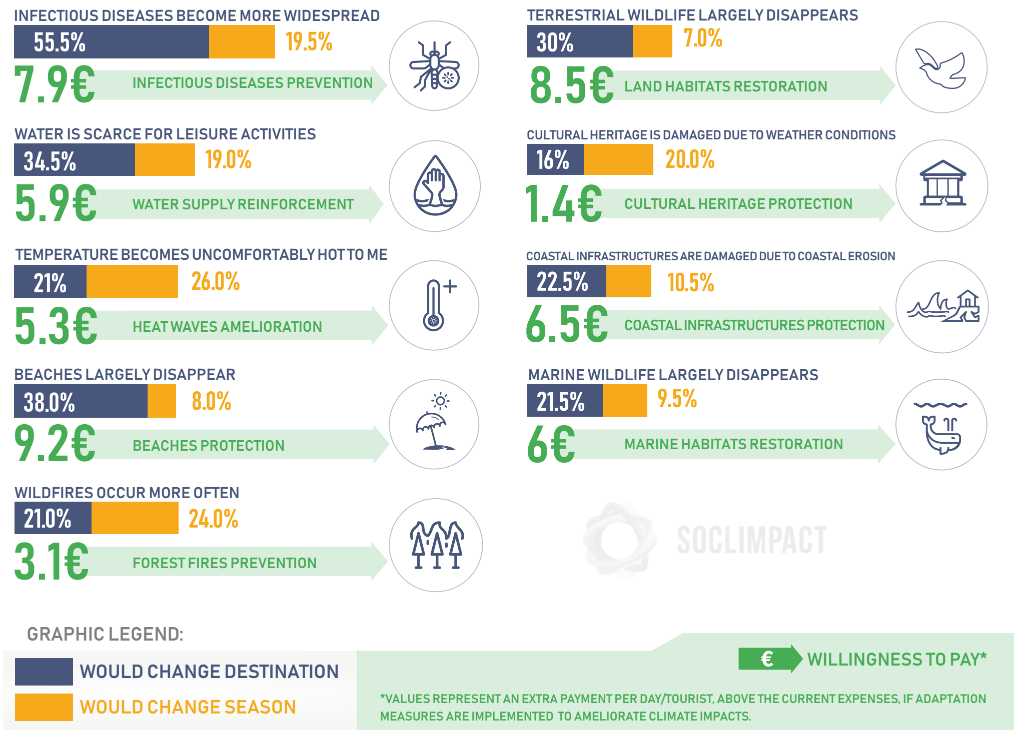


Figure 12.8. Tourists' response to climate change impacts and related policies: tourists visiting West Indies.

Source: SOCLIMPACT Deliverable Report D5.5. Report on market and non-market costs of Climate Change and benefits of climate actions for Europe.

12.5. Towards Climate Resiliency

The implementation of public policies specific to the issue of climate change and sea level rise in a sustainable development approach has not really succeeded in a context of economic and social crisis.

The acceleration of urbanization is an amplifying factor that will aggravate the impact of climate change, specially around the coastline, which is densely populated. Both islands under analysis, Guadeloupe and Martinique, are popular tourist destinations, thus tourist activity may be affected by climate change. Indeed, beaches are likely to experience a strong regression, yet they constitute attractive supports for the development of tourism.

These two tropical islands are also regularly subjected to the violence of cyclones and tropical storms whose wind and rains overexpress numerous hazards of flooding, landslides and cyclonic swells. Droughts can also at certain periods weaken the environment, making them more sensitive to the heavy rains that may ensue.

Due to the small size of the territories, it is difficult to resolve the climatic models at the scale of the Lesser Antilles and to assess the impacts of global warming by 2100. The problem of an evident lack of high-resolution wave simulations comprising this Atlantic island is a limiting factor for the analysis of climate change impacts. While the Mediterranean region is sufficiently covered by already available wave and surge data, available wave climatology over the Atlantic Ocean has too low resolution. Stakeholders should be made aware that uncertainty is an inherent characteristic of climate data, and that any future planning must cope with it.

There is a lack of reliable statistics and information related to exposure and vulnerability of the island to climate change. These are important components that worsen climate risks and respond to human interventions (more pressure). The island' s adaptation focus should be, first, the development of reliable information systems for the periodic monitoring of these components.

12.5.1. Policy Recommendations

A stakeholders consultation process was carried out in the island, aiming to propose, analyse and rank alternative adaptation measures for the island. The profile of the individuals participating in these focal groups involved policy and decision-makers, practitioners, non-governmental and civil society organisations, science experts, private sector, business operators and sector regulators at island level.

The main aim of these meetings was:

1. Identify and present the characterized packages of adaptation and risk management options for the island.
2. Develop detailed integrated adaptation pathways, in three timeframes: Short term (up to 2030), Mid-century (up to 2050) and End-century (up to 2100).
3. Evaluate and rank adaptation options for 1 blue economy sectors in the island (tourism).

To this aim, stakeholders utilized five evaluation criteria to rank the proposed measures:

- Cost efficiency: Ability to efficiently address current or future climate hazards/risks in the most economical way.
- Environmental protection: Ability to protect the environment, now and in the future.
- Mitigation win-wins and trade-offs: Current ability to meet (win-win) or not (trade-off) the island / archipelagos mitigation objectives.
- Technical applicability: Current ability to technically implement the measure in the island.
- Social acceptability: Current social acceptability of the measure in the island.

Four scenarios of intervention were analysed, called Adaptation Policy Trajectories (APT), which are different visions of future policy adaptation choices:

- APT A Minimum Intervention - Low investment, low commitment to policy change.
- APT B Economic Capacity Expansion - High investment, low commitment to policy change.
- APT C Efficiency Enhancement - Medium investment, medium commitment to policy change.
- APT D System Restructuring - High investment, high commitment to policy change.

It was assumed that adapting to climate change may range from minimal to high cost, and from requiring a small or incremental change to a significant transformation from the *status quo*. However, not all APT scenarios were considered in all islands, especially when their stakeholders had a clear vision on the types of measures with greatest viability. Therefore, the final set of proposed adaptation measures are framed in the islands' socio-economic and political context, have a sectoral perspective, and respond to the islands' future scenarios of climate change. At the same time, the involvement of regional stakeholders in policy design allows them to engage in the effective implementation of climate actions on their island.

In appendices from K to N, a brief explanation of each adaptation option can be found, classified by type or class: Vulnerability Reduction, Disaster Risk Reduction, Social-Ecological Resilience, and Local Knowledge. The latest group refers to very specific measures proposed by stakeholders in each island to ratify the needs.

12.5.1.1. Tourism

The general aspect of the selected pathway adaptation shows numerous situations of ties between the adaptation options. Concerning Vulnerability Reduction, the stakeholder choice fell on financial incentives to retreat from high-risk areas at the beginning and middle of the century, and then on economic policy instruments for the late century.

Activity and product diversity is the preferred option on all four APTs and all time horizons (short term, medium term and long term). However, there is a tie situation with the public awareness programmes for APT A in 2030 and 2050 and APT C in 2030. Regarding social capital, there is a tie in 2030 between the tourism awareness campaigns and the local circular economy. But, the circular economy should be implemented on the medium term and long term.

Concerning the natural capital, the choice went to local sustainable fishing. It reflects a concern about the resource, which is currently very limited in the French West Indies. The water restriction option is tied in the APT C in 2050 with local sustainable fishing.

Concerning Disaster Risk Reduction, the priority is given to the drought and water conservation plans for the APT A, B and C in the short term. Coastal protection structures appears from the medium term and long term on the three APTs. There is equality between the two measures for APT A in 2050 and also for APT C and D in 2100. As far as preparedness is concerned, mainstreaming Disaster Risk Management is the option chosen throughout the century. The use of water to cope with the heat wave appears in 2100. While the major concern is to improve the health system, forest fires are not considered a priority in the short/medium terms.

On the subject of provisioning services, the adaptation of groundwater management appears early in the APT B, C and D. Monitoring systems is the only measure applied in APT A. For APT B and D, it is implemented from 2050 onwards. On APT C, it is implemented throughout the century with a tie with T3 in 2030.

For Local Knowledge, the conservation and restoration of coastal forests is the measure chosen for APT A and throughout the century. It also appears for APT B and C in 2030. This measure enables several ecosystem functions to be fulfilled, such as the natural protection of the coasts against climatic risk, but also a tourism asset.

Improving the use and distribution of water is the adaptation measure considered most relevant on APT B from 2050 and throughout the century for scenarios C and D. Finally, the reinforcement of priority infrastructure concerns buildings and public facilities (restaurant, first aid post, road axis, etc.) in order to make them resilient, such as the construction of a modular restaurant along the beach. This measure only appears on the APT C in 2030. There is also equality between the three Local Knowledge measures for this year (see **Table 12.2**).

Table 12.2. Proposed adaptation options for tourism in the West Indies.

<table>
<tr><td rowspan="7">APT A – Pathway
—
Minimum Intervention
low investment, low commitment to policy change
—
This policy trajectory assumes a no-regrets strategy where the lowest cost adaptation policies are pursued to protect citizens from some climate impacts</td><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td>Public awareness programmes</td><td colspan="2">Activity and product diversification</td></tr>
<tr><td colspan="2">Drought and water conservation plans</td><td>Coastal protection structures</td></tr>
<tr><td colspan="2">Health care delivery systems</td><td>Fire management plans</td></tr>
<tr><td>Post-disaster recovery funds</td><td>Pre-disaster early recovery planning</td><td>Post-disaster recovery funds</td></tr>
<tr><td colspan="3">Monitoring, modelling and forecasting systems</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="10">APT B – Pathway
—
Economic Capacity Expansion
high investment, low commitment to policy change
—
This policy trajectory focuses primarily on encouraging climate-proof economic growth but does not seek to make significant changes to the current structure of the economy</td><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td colspan="3">Coastal forest restoration and protection</td></tr>
<tr><td colspan="2">Financial incentives to retreat from high-risk areas</td><td>Economic Policy Instruments (EPIs)</td></tr>
<tr><td colspan="3">Activity and product diversification</td></tr>
<tr><td colspan="3">Beach nourishment</td></tr>
<tr><td>Drought and water conservation plans</td><td colspan="2">Coastal protection structures</td></tr>
<tr><td>Adaptation of groundwater management</td><td colspan="2">Monitoring, modelling and forecasting systems</td></tr>
<tr><td colspan="3">River rehabilitation and restoration</td></tr>
<tr><td>Coastal forest restoration and protection</td><td colspan="2">Improve the use and distribution of water</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="12">APT C – Pathway
—
Efficiency Enhancement
medium investment, medium commitment to policy change
—
This policy direction is based on an ambitious strategy that promotes adaptation consistent with the most efficient management and exploitation of the current system</td><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td>Public awareness programmes</td><td colspan="2">Activity and product diversification</td></tr>
<tr><td>Tourist awareness campaigns</td><td colspan="2">Local circular economy</td></tr>
<tr><td>Local sustainable fishing</td><td>Water restrictions, consumption cuts and grey-water recycling</td><td>Local sustainable fishing</td></tr>
<tr><td>Drought and water conservation plans</td><td colspan="2">Coastal protection structures</td></tr>
<tr><td colspan="2">Mainstreaming Disaster Risk Management</td><td>Using water to cope with heat waves</td></tr>
<tr><td>Adaptation of groundwater management</td><td colspan="2">Monitoring, modelling and forecasting systems</td></tr>
<tr><td colspan="3">River rehabilitation and restoration</td></tr>
<tr><td colspan="3">Adaptive management of natural habitats</td></tr>
<tr><td>Coastal forest restoration and protection</td><td>Improve the use and distribution of water</td><td>Reinforcement of priority infrastructures</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="8">APT D – Pathway
—
System Restructuring
high investment, high commitment to policy change
—
This policy direction embraces a pre-emptive fundamental change at every level in order to completely transform the current social-ecological and economic systems</td><th>Short-term (up to 2030)</th><th>Mid-century (up to 2050)</th><th>End-of-century (up to 2100)</th></tr>
<tr><td>Financial incentives to retreat from high-risk areas</td><td colspan="2">Economic Policy Instruments (EPIs)</td></tr>
<tr><td colspan="3">Activity and product diversification</td></tr>
<tr><td colspan="3">Local sustainable fishing</td></tr>
<tr><td>Coastal protection structures</td><td colspan="2">Drought and water conservation plans</td></tr>
<tr><td colspan="2">Post-disaster recovery funds</td><td>Pre-disaster early recovery planning</td></tr>
<tr><td>Adaptation of groundwater management</td><td colspan="2">Monitoring, modelling and forecasting systems</td></tr>
<tr><td colspan="3">Improve the use and distribution of water</td></tr>
</table>

Vulnerability Reduction | *Disaster Risk Reduction* | *Socio-Ecological Resilience* | *Local Knowledge (provided by local stakeholders)*

Source: SOCLIMPACT Deliverable Report – D7.3. Workshop Reports.

Conclusions and Recommendations

SOCLIMPACT

This project has received funding from
the European Union's Horizon 2020 research
and innovation programme under
Grant Agreement No 776661

In a nutshell, the novelties of this research work are, on the one hand, to effectively use a participatory process involving 12 islands' stakeholders and academics to produce precise and adapted projections of climate change for the context of the islands, taking into account the relationship between climate change scenarios, biophysical impacts, and each island's specificities. On the other hand, it addresses the problem of an evident lack of high-resolution wave simulations comprising the Atlantic islands, by the expansion of the Med-Cordex database and the size of atmosphere-ocean coupled simulations, not published as of today. While the Mediterranean region is sufficiently covered by already available wave and surge data, climatological datasets describing surges in the Atlantic Ocean, and specifically for the islands analysed, are generally lacking. Available wave climatology over the Atlantic Ocean has too low resolution; and new dedicated simulations were performed, with results that are very satisfactory. Aditionally, the assessment of market and non-market effects in four key areas of the EU blue economy (aquaculture, tourism, energy and maritime transport) was undertaken by running discrete choice experiments and benefit transfer functions, both techniques with very limited application to this type of studies. Finally, the estimations of the climate change impacts on the islands' socio-economic systems were undertaken by combining structural and functional linkages between the islands and the rest of the EU with a newly combination of two general equilibrium models.

Climate Hazards' Projections with Relevance for the Tourism Sector

Potential Fire Behavior and Exposure

According to the analysis of the FFMC and DC codes, it seems that the "extreme" fuel moisture categories strongly vary among subareas (NUT3). The most relevant variations in FFMC and DC were observed in the distant future period under RCP8.5 scenario across all climate models, and the increase in the frequency of the driest days suggests that the fire seasons will be longer than the baseline period.

Variability in FFMC and DC codes strongly influences fire characteristics. Overall, under the RCP2.6 BP, CFL, and FS seem closer to the present conditions towards the end of the century, especially in Sardinia and Corsica. On the other hand, under the RCP 8.5 the increase is much more prominent, ranging from 7 % to 41 %, according to fire characteristic and climate models.

Therefore, the projected results suggest an increasing vulnerability of ecosystems and anthropogenic assets to larger fire that could lead to greater losses and escalating firefighting costs. In addition, the projected increase in wildfire risk is likely to lead to a significant increase in atmospheric emissions. This aspect not only contributes to global warming but has also an important impact on local and regional air quality and eventually implications for human health.

Thus, the information concerning burn probability and intensity maps can contribute to (i) map fire behaviour changes due to climate change, and to (ii) support fire managers, decision and policy-makers to respond to the potential increase on fire vulnerability and risk, thus contributing to long-term low-carbon transition. Below we include possible recommendations to incentivize EU islands decarbonization, strengthening science-policy interface, increasing social awareness, and contributing to the competitiveness of the European tourism industry.

- Advance in analysing, quantifying and mapping fire behaviour, hazard, risk, and exposure to identify vulnerable areas and to better address mitigation, adaptation and planning policies.
- Identify people and properties at higher risk and enforce protection and self-protection.
- Raise awareness, education and consciousness of the fire-related risks through training and educational campaigns on fire propagation and potential risks, and on what measures we need to apply to reduce potentially dangerous behaviors or actions.
- Develop guidelines to build a "firewise" community, developing strategies and urban plans to minimize risk and losses.
- Foster active forest management to mitigate risk.
- Reduce landscape susceptibility to wildland fires while maintaining ecological diversity through dead and live fuel removal, weed and flammable shrub control, and creation of fuel discontinuity in strategic areas (including wildland-urban interface, very common in touristic areas.

Evolution of Beaches

The fate of the beaches in European islands is of paramount importance as it is one of the main assets for tourism activities. Sea level rise and changes in the wave climate would put at risk the beaches as a significant loss of beach area could be expected. Quantitative projections of beach evolution are not available for most European islands, mainly due to the difficulties associated with the required computations. In this work, a new methodology has been deveolped allowing cost-effective and yet accurate estimate of wave runup for different types of sand beaches. This, combined with recent projections of sea level rise and wave climate, has allowed a quantification of the flood level for all European islands as a function of time horizon GHG scenario and beach granulometry. In a second step, this information has been transfered to coast retreat and beach area loss for the Balearic islands, where detailed information on beach granulometry and current area was available.

In order to translate this information to quantitative indicators to be used in the operationalization of the impact chains, we assume that the distribution of beach types is similar in the different islands. Thus, a rough estimate of the beach surface loss in each island could be derived from the results obtained for the Balearic islands, by scaling the percentage by the mean flood level in each island. Then, the area loss can be directly translated to a normalized indicator ranging from 0 to 1. That is, a loss of 50% of beach surface would represent a hazard of 0.5.

Seagrass Evolution

Seagrasses are the main habitat for coastal marine ecosystems. They provide different services like sediment retention (and thus, clearer waters), coastal protection (in front of marine storms), shelter for marine organisms, etc. Therefore, the state of the seagrasses is a convenient proxy for the state of coastal environment. Here we have analysed temperature projections for different European Islands and assessed whether the upper thermal limit of the main four foundation species would be met under different climate change scenarios. Our results suggest that noticeable seagrass losses could be expected under scenario RCP8.5 by the end of the century. In particular, the losses would be concentrated in the Western Mediterranean (Balearic, Sardinia, Malta and Sicily) in which the coverage of Posidonia Oceanica would be reduced between a 14 and 35%. In the eastern Mediterranean, the thermal threshold is higher as far as Posidonia has adapted to the warmer conditions, and thus it is more resilient to projected warming. Although the projected reduction may seem moderate, it should be noted that the losses will be localized in the nearshore areas, so a large impact on water transparency is expected in beach areas. Ecosystem services will probably be less affected.

Climate Hazards' Projections with Relevance for the Energy Sector

Energy Productivity Indicators

Wind energy productivity decreases in general over the Mediterranean Sea as a consequence of anthropogenic climate change, consistent with previous studies. This decrease is more important for RCP8.5 scenario. Crete shows a different trend, with increases over most of the domain at mid-century in both emissions scenarios, and large spatial contrasts at the end of the century for RCP8.5 scenario. Climate change over the Baltic Islands affects wind energy productivity in a different way, showing possible increases or little change for RCP8.5, while a decrease is projected for the lower emissions scenario. Over the North Atlantic, a particularly interesting result is the increase of wind energy productivity found in the Canary Islands for RCP8.5 scenario.

Photovoltaic productivity slightly decreases over the Mediterranean islands, as has been also observed in previous studies, but the relative change of this indicator is rather low in general. The impact of the possible anthropogenic aerosol reduction on surface radiation in the area has not been considered in these projections. This is an uncertainty source that could modify the future change of photovoltaic productivity towards no variation or even small increases.

Projected changes of PV productivity over the Atlantic islands are generally very small, with a prevailing slight increase over land. Due to the coarse resolution of the models over the Atlantic, in comparison to the land area of the islands, these results should be taken with caution. Baltic Islands are the most affected by climate change, with a higher relative decrease in PV productivity, particularly for RCP8.5 scenario. Such a trend has also been projected in previous studies.

In the Canary Islands domain, wind and PV productivity show the same seasonality, with a maximum during summer months, which indicates a reduced complementarity between both technologies. In Crete, wind has a more stable seasonal cycle with smaller differences among seasons. However, a maximum appears in winter, whereas there is a minimum in PV productivity during winter months, indicating some complementarity between both sources. In the Cyprus domain, both technologies complement each other as well: low values of wind productivity coincide with high values of PV productivity during summer, while the opposite occurs in winter.

Energy Productivity Droughts

In the studied regions, in the control time period, wind droughts are generally much more frequent than PV droughts. This highlights the steadier nature of PV productivity over time. The annual frequency of PV droughts is largely determined by winter and autumn insolation, given that in spring and summer they are almost non-existent.

In the control time period, the frequency of PV droughts is similar in all regions, with values around 10% of the days for moderate droughts and very low values of around 1% for severe droughts, with the exception of the Baltic Islands, where both type of PV droughts are clearly more frequent. Lower latitude islands show generally lower PV drought values, with a minimum over Canary Islands, where moderate droughts occur on less than 6% of the days, and severe droughts are almost non-existent. Wind droughts are clearly more frequent in the Mediterranean islands (with values around 50% of the days for moderate droughts and 30% of the days for severe droughts) than in the Atlantic Islands.

Variations in the frequency of productivity droughts in the RCP2.6 and RCP8.5 scenarios compared to the control time period are small in general, with a maximum magnitude of about 5% of the days. Changes tend to be greater (in magnitude) in the RCP8.5 scenario than in the RCP2.6 case.

The seasonal cycle of moderate PV droughts is qualitatively the same in the Canary Islands, Crete and Cyprus domains: droughts are maximum in winter and are almost non-existent in spring and summer. This pattern is caused by an increased cloudiness in winter and a prevailingly anticyclonic situation in summer. The seasonal cycle of moderate wind droughts in the Canary Islands, Crete and Cyprus domains is qualitatively different. The fact that a different seasonal cycle is found in Crete and Cyprus, despite their geographical proximity, underlines the great spatial variability of wind regimes like the Etesian winds in late spring and summer.

Interestingly, in the Canary Islands, where energy productivity droughts show comparatively low values, a remarkable drop in their frequency in the RCP8.5 scenario is projected. In the Baltic Islands, an important increase in the frequency of PV droughts is projected for the RCP8.5 scenario, for which moderate droughts increase about 5%.

The combination of PV and wind energy is very beneficial in terms of drought frequency for most of the Mediterranean islands, as moderate combined droughts show a frequency that is much nearer to the low PV drought frequency than to the high wind drought frequency. Severe combined droughts are very infrequent in all Mediterranean islands, even below the severe PV drought frequency in several of them. This points to a notable complementarity of wind and PV energy in many Mediterranean islands.

In Canary and Madeira islands, the frequency of moderate combined droughts is comparatively high, and nearer to the wind drought frequency. The case of the Baltic Islands is particularly interesting, as the combined drought frequency is not only below the wind drought frequency but also below the PV drought frequency, both for moderate and severe droughts. This points to a high complementarity of PV and wind for the Baltic islands.

All previous results have been obtained for land points. For most Mediterranean islands, the frequency of severe combined droughts over many sea points near to the coast is nearly zero. This indicates that a potential future deployment of combined offshore wind/PV platforms near the coast would have two important advantages: a clearly higher productivity than over land (as wind productivity increases rapidly over the sea with the distance to the coast) together with a reduced daily variability. This could limit the need for energy storage and backup sources in case of high solar and wind energy shares in the electricity mix.

Climate Hazard Projections with Relevance for the Maritime Transport Sector

The hazard indicator analysed was the extreme sea water levels (ESL) arising from the superposition of waves, surge and projected sea level rise. A first evaluation of shoreline retreat was attempted for the Mediterranean islands, by combining the mid-century mean and highend Sea Level Rise (SLR) projections and GIS-based data of near-shore slopes along the European coast.

Projections on SLR for the Atlantic Islands rely on CMIP5 global model (1° x 1° spatial resolution), and take into account the oceanographic circulation, the thermo-steric component and the ocean mass increase due to continental ice melting, as well as gravitational and viscoelastic deformations (originating from continental ice melting and changes in land water reservoirs) and the regional pattern of the Glacial Isostatic Adjustment (GIA), which were obtained from independent gravitational and viscoelastic models. For the Mediterranean, local differences with respect to the sea level in the North-Eastern Atlantic were computed from the higher resolution regional oceanographic experiments, performed within the MED-Cordex programme, which account for the sea level drop across the Gibraltar Strait. As regional simulations do not include the atmospheric pressure loading, the latter was estimated from Regional Barotropic Models (RBMs). It must be noted that the use of regional models constitutes an improvement with respect to even very recent approaches that, on recognition that global models are inadequate for the assessment of regional sea-level in marginal seas, yet constrain the Mediterranean sterodynamic sea-level projections to those of the Atlantic in proximity of the Gibraltar Strait, the entry point to the Mediterranean Sea.

Averaged sea level rise results show slight differences among islands with relative differences in SLR lower than 25%. For instance, the largest SLR is found for Madeira under the RCP8.5 scenario at the end of the century (74.72 cm). For the same scenario and timeframe, the smallest SLR is found for the Baltic islands (56.60 cm) a 24% lower. Also, the SLR is expected to be larger in the Atlantic islands, and as expected, also larger at the end of the century and under the RCP8.5 scenario. It is worth to say that under extreme conditions, the effect of the runup, which does not depend much on the scenario, is much more important than the mean sea level rise.

Analyses are on-going to further synthetize results into a climate-change dependent coastal vulnerability index for the Mediterranean Islands, in order to integrate information from a multi-dimensional set of physical, geological, and, when feasible, socio-economic variables. Albeit such large-scale analyses cannot serve as the basis for local intervention, which demands *ad hoc* monitoring and planning, they can effectively contribute to increasing social awareness as to climate change related hazards for insular communities, and help recognize the potential economic disadvantage faced by islands and highlight the most urgent priorities.

Risk Assessment

For the aquaculture sector, future wave-induced risks, even under the worst-case scenarios, are not expected to exceed medium scores for all the Mediterranean islands. This still holds if wave periods are considered as they remain around 5 sec, a moderate/medium risk class if considered in combination with the relatively low SWH. With respect to extreme weather, Malta, southern Sicily and west Sardinia are found to be the most critical areas, Sardinia and Sicily also exhibiting higher vulnerability, as the local sector includes a high percentage of mussel culture, which is more sensitive than fish farming. The main impact of climate change is expected to be associated to warming seawater. However, a thorough assessment of its consequences for the productivity of farms would need additional specific modelling efforts in close collaboration between enterprises and scientists. In this case, as for the less threatening wave-induced hazard, Malta is liable to exhibit the highest risk score, due to its higher exposure.

Rising temperatures are also directly and indirectly responsible for the expected increase in energy demand, caused either by the necessity of guaranteeing public safety, health and food security through widespread access to electric cooling, or by the need of an additional supply of desalinized water. The Atlantic islands show a more contained increase of CDD than the Mediterranean islands, while the SPEI decrease is similar in both basins. One reason for this different behaviour can be the higher sea surface temperatures of the Mediterranean Sea in summer. Another factor may be the different wind regimes in summer, as trade winds are strong and persistent over Canary Islands and Madeira, contributing to moderate temperatures, while over the Mediterranean Sea winds are generally low in summer. In general, the risk induced by the increased cooling demand is lower and less uniform than that associated to increased desalination, as the drought hazard scores indicate a much more homogeneous and extended impact on water availability. A reason for this is that more severe drought conditions will develop due to the superposition of two trends, the temperature increase and the precipitation decrease, both in the Mediterranean and Atlantic islands, under the high-emissions scenario (RCP8.5). It is an open question if on long time-scales (several decades, variations between 20-year average values) the impact of the climate hazards is larger, but this seems reasonable, as cumulative effects of persistently higher temperatures and sustained droughts will likely have a profound effect on the cooling and desalination energy demand. In order to fulfil the augmented demand, renewable energies like wind and solar are a safe bet, as they will maintain its present potential with only limited and slow changes, that will be even positive in some cases.

Thus, coming to the supply side, the frame for the energy sector are the binding targets established in the 2030 climate and energy EU framework and the long-term horizon of a decarbonized energy system by 2050. The future change of wind energy and PV productivity should be rather small in general: around 5% or less with respect to the reference period in many cases, with maximum changes of about 10% for some islands at the end of the century under RCP8.5 scenario (particularly for wind energy productivity over land). A 10% productivity change could have a significant impact on a planned or existing plant if it occurs over the lifetime of the power plant, but in this case such a change would extend over many decades, which will facilitate adaptation and efficiency measures. In general, projections show a decreasing tendency of wind energy productivity over the Mediterranean region, with a more important decrease for the RCP8.5 scenario. The main exception is Crete, which shows a consistent increasing tendency. Projected PV productivity changes are generally smaller than wind energy changes. In most cases, PV productivity remains constant or slightly decreases. The main exception is Fehmarn, which shows a clear decreasing tendency in PV productivity under RCP8.5 scenario, reaching a 10% decrease by end of the century.

As part of the pathway towards very high or 100% RES shares, offshore wind energy should play a very relevant role, although solutions need to overcome the obstacle posed by the deep bathymetry surrounding most of the islands. Nevertheless, some technologies are now approaching commercial deployment, and floating offshore wind plants are already planned near Gran Canaria and Sicily. Offshore PV could also be an interesting option for some islands, particularly when land surface limitations are large. There is growing interest in this option, as shown by the test plants being installed and the references made to this technology in the Roadmap for the Offshore Renewable Energy Strategy of the European Commission or in the report of Monitor Deloitte and Endesa (2020) about the accelerated decarbonization of Canary and Balearic Islands.The combination of different types of offshore renewable energy sources in the same platform is also attracting interest, as the different sources can exhibit complementarity in time and the combined output can thus be more stable and reliable. The different RES can also share part of the installations, like the connection to land, reducing their cost.

The European Union is trying to promote such combinations, through projects like MUSICA (Multiple Use of Space for Island Clean Autonomy) which will design and test a floating offshore platform integrating wind, PV and wave energy for use on islands (MarineEnergy, 2019b), and plans to develop roadmaps for its deployment in three case study islands, among them Malta and the Canaries (MaREI, 2020). Interconnections to the mainland will anyway remain very important for supply safety, although excessive dependency on interconnections to mainland should be avoided, to reduce the risk of blackouts, as the failure of a single element (one transmission line) can knock out instantaneously a large proportion of the power of an island and even cause an island-wide blackout, as has occurred several times in Malta in the last years. Again, Malta is particularly vulnerable to climate change impacts on the energy sector: on the demand side, nowadays, it already has a high rate of cooling installations and a high percentage of desalinated water with respect to total water consumption, so that future temperature and drought increases will worsen an already difficult situation; on the supply side, it is an island with large constraints on onshore wind and PV energy, due to its small size and large population density.

There are also physical obstacles for the installation of offshore wind energy plants, such as the local deep bathymetry. However, Malta has already applied strong demand side management measures in the water sector through the significant reduction of water leakages from 2004 to 2009. This factor has been decisive in the evolution of the desalination energy demand, which decreased by 20% from 2004 to 2018. During the same period, the GDP grew by 80%, the number of tourists doubled and drought conditions worsened. The downside of this positive results is that the possibilities for further action in this respect are very limited. New financing possibilities linked to the recently approved EU COVID-19 recovery fund and, over the longer term, associated to the European Green Deal, should facilitate the deployment of renewables in the islands, as the energy transition is a key target. Indeed, accelerating the transition to a decarbonized society would effectively counteract future risks, as there is a radical contrast between the scenario in which robust emmision reduction policies are implemented (RCP2.6), as well as the high-emissions scenario (RCP8.5). Not only are the hazard scores much lower for RCP2.6, but they even tend to decrease slightly during the second half of the century, while for RCP8.5 the hazard scores tend to rise in a sustained way. Nevertheless, the full implementation of an energy system based on RES requires further progress in the automation of energy production and distribution, so as to integrate variable sources of electricity into the distribution grid and to automatically minimize the impact of generation peaks and troughs, thus maintaining a constant balance between electricity supply and demand, avoiding a blackout or any other cascading problem.

Consistently with the moderate/medium risk associated to wave-induce hazard in aquaculture, the future risk for maritime transport disruption is not expected to exceed medium risk scores, even under the business-as-usual pathway. As expected, our analysis highlighted a higher risk for most islands towards the end of the 21st century and under the business-as-usual RCP8.5. Malta was found to be most vulnerable (risk values 0.335-0.414) also as to the maritime sector. This is because of the higher exposure and vulnerability components in this particular island. On the contrary, Corsica is the island less susceptible to climate change impacts (risk values 0.194-0.273). For some islands (e.g., the Canary Islands), the future risk increase is constrained by a reduction of the exposure indicators, which are driven by population decrease. This is found to counterbalance the projected augmentation of climatic conditions due to climate change.

Regarding the tourism sector, tourism-related industries represents a significant component of the GDP in European islands, and all projections agree that such relevance is expected to be maintained throughout the 21st century. Tourism is strongly dependent on climate, and consequently, climate change may significantly affect this sector, altering the geography of international and domestic tourist flows, and possibly requiring resizing/restructuring efforts and the development of new products and activities.

The selected ICs are representative of different dimensions regarding the complex relationship between climate change, the ecosystems affected by climate change, and the environmental services, those ecosystems sustain coastal and marine tourism in European islands. The weather discomfort IC reports on the direct impact of changes in climate variables on the comfortability of vacation stays in the islands. The forest fire IC informs on the impact that this climate change powered phenomenon may pose on the terrestrial ecosystems that hold the rich and endemic biodiversity of the islands, which in turn it is a patrimony of all Europeans; fires also put at risk public and private assets and the safety of tourists and residents. The marine habitats IC accounts for the impacts of climate change on the ecosystem that mainly supports the coastal and marine tourism activities, such as seawater bathing, diving, snorkelling, surfing and windsurfing.

The main purpose of the risk analysis is to compare the above mentioned risks among a selected set of European islands. For the case of thermal, the relatively smooth expected changes in the hazard component over the Atlantic region surrounding the Canary Islands were determinant for this archipelago to be located at the low end of the risk scale, despite its high socio-economic exposition. At the other extreme, under the RCP8.5 scenario (no control of emissions), Cyprus is expected to experiment notable higher variability and periods of extreme high temperatures both in the atmosphere and the ocean, as well as additional stresses on its marine environment originating from the neighbor Red Sea. Cyprus, therefore, exhibits the highest risk scores, its adaptive capacity not being sufficient to compensate for the hazards. The Balearic Islands show comparatively high risk for marine habitat degradation, due to very high natural and industrial exposition, while the irrelevance of sun and sand tourism (low exposition) makes Malta display a relative low risk from marine habitat degradation, although significantly higher scores as to thermal discomfort. For Sicily, which is significantly exposed to marine habitat degradation, the main strength in coping with climate change threats is represented by its potential to substitute marine-based tourist activities, thanks to its extraordinary endowment of assets in culture, inland landscapes, gastronomy and archaeology. Finally, Sardinia benefits from a relative low risk from thermal discomfort, due to the relative mild hazard, intermedium level of exposition and medium-high adaptive capacities.

Concerning forest fires, for the reference period (1986-2005), the overall risk is medium for Atlantic Islands (Madeira and Canary Islands – predominance of the exposure component) and Eastern Mediterranean Islands (Crete and Cyprus – predominance of the hazard component). Risk for other islands is low (Sicily and Balearic Islands – predominance of the exposure component, Corsica and Sardinia – predominance of the vulnerability component) and very low for Malta (the only island with a quite balanced distribution across components). The hazard scores increase from west to east and from north to south, with the exception of Malta, which is much smaller, and where the selected grid cells are mostly influenced by maritime conditions. Under RCP2.6, fire danger appears to return to present conditions towards the end of the century, except for Crete, whose score will increase from medium to high. Under RCP8.5, the increase is much more prominent, ranging from 22% to 46%, with the highest values for Corsica, Sardinia and Sicily, which implies that under this scenario at the end of the century, the western and central Mediterranean will be more affected.

As to the exposure component, Atlantic Islands (Madeira and Canary Islands) exhibit higher values than Mediterranean islands (from low to medium score), while in the Mediterranean basin it increases from north to south. This result is mainly explained by differences in the level of exposure rather than in its nature, which shows similar values across Mediterranean islands, except for Malta, whose score is very low. However, the specific characteristics that determine the nature of exposure vary across islands, despite such comparative homogeneity: Corsica has the highest score for forest areas, followed by Madeira and the Canary Islands. The latter two, in particular, have the highest score for forests belonging to protected areas. We can find a significant proportion of cultivated areas in other islands, such as Sicily, Sardinia, Balearic Islands, Crete and Cyprus. At the same time, the level of exposure is particularly important for the Canary Islands and Madeira due to their high scores in each of the 4 considered indicators: population density, population over 65 years, population under 9 years, and tourist density.

In terms of vulnerability, results show large variability across islands. The vulnerability score for Corsica is very high, followed by Sardinia (high), Madeira, Balearic Islands, Cyprus and Crete. The scores for Malta, Canary Islands and Sicily are low. Breakdown by sub-component highlights quite homogeneous scores for adaptive capacity, whereas sensitivity scores (Flammability Index) are very different across islands, Corsica and Sardinia having the highest scores, and Malta, Sicilia and Canary Islands the lowest. As to the adaptive capacity sub-component, despite its quite homogeneous scores, factors of influence are quite different across the islands. It must be noticed that all islands, apart from Crete and Sicily, have high scores for employees in the primary sector, indicating low ability to adjust to changes. Cyprus presents a very high score for education, which is, on the contrary, very low for Madeira, Corsica and Malta. Scores for density of firefighters and volunteers are very high in Crete, Canaries and Malta and high for the rest of the islands except for Cyprus (medium).

From a wider perspective, when European islands are compared to other competing tourism destinations, it is worth reflecting on the overall risk they are expected to face. In islands, the proximity of the sea mitigates temperature variability with respect to continental territories, which means they maintain a relative advantage as to weather comfort. For example, the Canary Islands are now perceiving a recovery in summertime fluxes originating from the regions of southern Germany that experience extreme temperatures. This must not distract the attention from the fact that European islands are a paradigm of clear waters and nice marine landscapes, and that they will, therefore, have to face demanding challenges to prevent the degradation of their marine habitats. The complete elimination of other human-induced threats to marine habitats other than climate change, such as sewage discharges, and the development of substitutive products and tourism activities that are less dependent of pristine marine environments will be crucial for European islands to keep their competitive position in global tourism.

Non-Market Analysis (Tourism)

In order to analyse the effects of climate change on tourists' behavior, two different field works were conducted based on respective survey instruments carefully designed in focus groups and pre-testing work. The first survey was conducted at origin countries. In these home countries, frequent travellers were asked how climate change impacts could affect their travelling decisions and their destination choice. In the second survey, conducted at 10 islands destinations of the project, tourists were asked how they would choose between alternative adaptation policies that could be implemented at the destinations they were visiting. Discrete choice experiments (DCEs) using a survey tool was the method selected for the study. The selection of attributes (impacts of climate change) and the policies (adaptation) included in the questionaire has been obtained from a combination of existing studies in the literature and the expertise of the researchers working on this analysis.

A total of 4,838 EU citizens (frequent travellers) were interviewed at their country of origin (United Kingdom, Germany, France and Sweden). These countries were selected because together they constitute the main outbound markets for tourism to the European islands, representing more than 60% of the tourists' arrivals in most of the islands or archipelagos of the project. The sample was taken randomly from the adult population of EU frequent travelers subject to the quotas of gender and age groups. In order to ensure population representativeness of the tourist niche market, potential participants in the survey were filtered by asking them if they had visited any Mediterranean islands or North Atlantic islands (Canary Islands, Madeira, Azores or Antilles) in the last five years, or whether they had planned to do so in the next year. If the answer was "no" to both questions, then the survey was finalized and the subject was invited to abandon the study.

A total of 2,528 tourists were interviewed at 10 different islands destinations: Azores, Balearic Islands, Canary Islands, Crete, Cyprus, Fehmarn Island, Madeira, Malta, Martinique & Guadeloupe (Antilles) and Sicily. Tourists were randomly chosen, but they were screened to be adults (18 years old or more), should had stayed at least one night at the island, and should have completed at least half of their stay. The survey work took place at both weekdays and weekends days to capture all groups of tourists.

From a qualitative perspective, it was found that tourists are highly prone to definitely change their destinations' choices if infectious diseases become more widespread, but also if temperature becomes too hot, if fires occur more often at destinations, and if water becomes increasingly scarcer. Some of these results are corroborated with the evidence obtained from the quantitative methodology of discrete choice experiments on the economic valuation of climate change impacts at islands destinations. That is, DCEs results at the island destinations show that tourists attribute the highest willingness to pay to policies dedicated to marine habitats restoration, followed by policies aiming at supplying sufficient water, preventing infectious diseases, and protecting the beaches. Further, results from the data DCEs collected at origin countries also show that tourists would change destination choices because of climate change impacts, and that these impacts would reduce significantly their willingness to pay to visit the European islands destinations. Those impacts that will have higher impacts on the economic value of tourism at the destinations are related with the higher risks of infectious diseases and the higher risks of forest fires, while those with lesser impacts on the economic value of tourism are concerned with the higher risks of heat waves and the expected reduction in beach space because of water intrusion.

The Economic Impacts on Aquaculture, Energy and Maritime Transport

For the case of the aquaculture sector, it was analysed the effect of the increased sea surface temperature on the production of the sector. These effects were calculated using a lethal temperature threshold by species and considering the production share of each region. The forecast of the water temperature increase in the four IPCC scenarios (RCP2.6 near, RCP2.6 distant, RCP8.5 near, RCP8.5 distant) was extracted from previous research. We assume that the biomass in each species is regulated by a thermal function, and that the monthly production depends on the monthly water temperature in every region. The analysis was conducted in 10 islands.

Overall, the great heterogeneity of results among islands, scenarios and time horizons highlights the importance of downscaling climate projections and of adapting them to the different economic characteristics of the islands. In this respect, it is also important to underline that economic projections also substantially differ between islands of the same region (Mediterranean Sea and Atlantic Ocean), once more calling for specific in-depth investigation of each territory. Some islands show negative impacts because of the representative proportions of the production of tuna and mussels, which are the most affected species. In other cases, the production function will not be negatively affected by the increased sea temperatures.

The assessment of the economic impact of climate change on the energy sector is centred i) on the evaluation of the additional demand of energy to lead with higher temperatures during the season prone to heat and ii) on the estimation of the costs associated to a higher consumption of water to compensate more elevated temperatures across the different domains of humans' activities (householding, gardening, etc.).

The relationship between the increase of temperature and the increase of energy demand for cooling is underpinned on the indicator denominated Cooling Degree Days (hereafter CDD). CDD are a measure of how much (in degrees), and for how long (in days), outside air temperature was higher than a specific base temperature. They are usually used for calculations relating to the energy consumption required to cool buildings. To estimate the increase of energy demand due to the increase in water demand, it was assumed that most of the islands (all the Mediterranean, the Canary Islands and, at least partially, the West Indies) will have to produce desalinated seawater (or groundwater) to meet further increases of demand. Consequently, the estimate of the increase in energy demand to produce more drinking water has been done based on the energy consumption required to desalinate seawater. The indicator used to translate the increasing temperatures into increases of drinking water demand is the so-called Standardised Precipitation Evapotranspiration Index (SPEI). The SPEI is an extension of the widely used Standardized Precipitation Index (SPI). The SPEI is designed to take into account both precipitation and potential evapotranspiration in determining drought. Thus, unlike the SPI, the SPEI captures the main impact of increased temperatures on water demand.

Results for the energy sector show that the impact of climate change is considerable, especially the one associated with an increase in demand for desalination energy due to changes in precipitation and temperatures. These changes range from moderate in Cyprus (from 3% to 8.9%) to very high in the Canary Islands (from 60.2% in RCP2.6, near future, to 103.3% in RCP8.5, distant future). The increase in demand due to change in CDD is less important, as it is partially outbalanced by a decrease in demand for heating degree days. Change in energy demand goes from about 4% to 6% in the two different time horizons of RCP2.6, and from 8.2% (Malta, near future) to 38.3% (Canary Islands, distant future) for RCP8.5.

Regarding maritime transport sector, the negligible change in the frequency and intensity of extreme events projected in the scenarios applied to the islands under investigation allows us to conclude that the cost of interrupted transport service, in the future, will be almost non-existent. It is then possible to focus on the impact of sea level rise (SLR) and make a simplifying assumption: as SLR happens slowly and gradually, it is likely that future investments will prevent any transport interruption; hence, the economic impact of SLR can be proxied by the cost of updating infrastructures to keep ports operating. Clearly, such procedure cannot be extended to regions where extreme events are likely to increase in the future.

These costs have been calculated with reference to 1 meter; this is, the investment needed to increase the infrastructures' height by 1 meter. There is not necessarily a strict correspondence between the SLR and the required elevation of all port infrastructures in the islands, which also depend on the coastal hydrodynamic and the shape of dikes of each port. By experts' recommendation, we have assumed that a 1 meter increase in port height is required to cope with the SLR under the RCP8.5 scenario of emissions. Extrapolation for other RCP scenarios is then conducted based on proportionality. As it was expected, the rising sea levels will affect the maritime transport sector, thus new investments will be needed to keep ports' operability in the future. Under the high emissions scenario (bussiness as usual), the costs of inaction could increase by 16 million euros per year by the end of the century.

Socio-Economic Implications of Climate Change for the Islands

The socio-economic analysis described in this report has identified tourism, maritime transport, aquaculture, and energy on the islands as the most climate change sensitive and economically relevant sectors. The modeling approach is described for each sector in turn and is the same across islands. The results, however, are presented by island. For the economic analysis, islands' Input-output tables have been updated for each island, in order to have a basis for the detailed analysis of the respective economy. Economic outlooks then haven been developed for the respective islands. In this report, these outlooks comprise the reference case to which the climate cases are compared. Climate change drivers on matching levels of scale are turned into economic direct impacts.

The two models employed (GEM-E3-ISL and GINFORS) differ in their time-horizon coverage. While long term simulation is standard for CGE models, (being structural optimization models), macro-econometric models are based on estimated time series from the past, and thus, only valid under a shorter time-horizon (Lucas critique). Macro-econometric models are characterized by a certain rigidity in adjusting to exogenous shocks, which is valid on mid-range simulations. In the long term, of course, the economy can better adjust, for instance, to a warmer climate. The economic modeling approach is twofold, one is close to the model also used for the PESETA studies, the second model applied is less constrained by the demands of equilibria.

In the short term (up to 2050), GDP results for both models are similar. For instance, GDP changes in the Balearic Islands reported by GEM-E3-ISL and GINFORS are between -1.5% and over 2% under RCP2.6, and between 2.5% and 3.5% under RCP8.5 until 2050. Sector specific changes, however, differ. While construction receives in both scenarios positive impacts, the spill-over effects into other sectors are more pronounced in the GINFORS model. Travel related sectors, of course, receive the negative impacts. Transport loses from increasing transport costs in GINFORS. The Islands' economies respond differently depending on their respective economic structure, the relevance of the blue economy sector hit hardest by climate change, i.e., tourism for the overall economy and the relevance of transport on the islands. The assessment suggests that islands should intensify their efforts for economic diversification, promoting local products and small manufacturers.

The exercise shows the importance of modeling all Islands individually, because the reactions to climate change and the damages in the respective sectors differ widely across islands and from the main countries. Malta and Cyprus, for instance, experience smaller GDP losses than the Canaries. The Azores, located in a colder area in the center of the Atlantic, suffer the least from climate change compared to all other islands. The analysis on the down-scaled level of islands helps to better inform and better target adaptation policies by Island decision makers.

In the future, modelling climate change and adaptation measures for the islands can be expanded. This includes more detailed economic data and further integrating models for the islands with the national level. It is important to understand the specific socio-economic developments and challenges of the islands in the future. Knowledge about damages due to climate change and effects of adaptation measures for the islands should be improved continuously in order to develop better design policies.

Recommendations for a Common Framework

The EU Strategy on Adaptation to Climate Change, (Brussels, 24.2.2021 COM (2021) 82 final) recognizes the outermost regions of the EU as particularly vulnerable to the impacts of climate change. These regions are characterized by their insularity, climate and biodiversity richness, as well as economic dependence on a limited number of economic activities or products, such as tourism (Sauter *et al.,* 2013). They are also heavily dependent on imported oil to cover their energy needs, especially regarding power generation. In the case of electricity, increased demand can be expected from rising temperatures due to presumed higher air-conditioning needs.

Addressing climate objectives of European islands is a challenge due to their location and, in some cases, isolation, and the resulting implications for costs of products and services. Also, the public support and the generation of funds needed to maintain the economic and social development follows different dynamics than on the European mainland.

Policy makers of these regions require detailed and precise information about the likelihood and dimension of the climate impacts at local scale. Adaptation options should depend on the conditions and background of each sector and location in focus. It is recognized that integrated complementary approaches need to be developed, which can benefit from the input of stakeholders at different times, setting critical thresholds for specific climate change vulnerabilities.

Adaptation can be based on uncoordinated, *ad hoc* choices and actions of individuals and different stakeholders, or based on collective choices, coordinating numerous actions at various levels - local, regional, national or supranational. Smart adaptation thus requires multidisciplinary knowledge, shared responsibility and actions coordinated between different governmental and non-governmental actors in different policy areas.

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SOCLIMPACT

This project has received funding from
the European Union's Horizon 2020 research
and innovation programme under
Grant Agreement No 776661

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Appendices

SOCLIMPACT

This project has received funding from
the European Union's Horizon 2020 research
and innovation programme under
Grant Agreement No 776661

CONTENTS

Appendix A: Impact Chains Analysed for the Tourism Sector

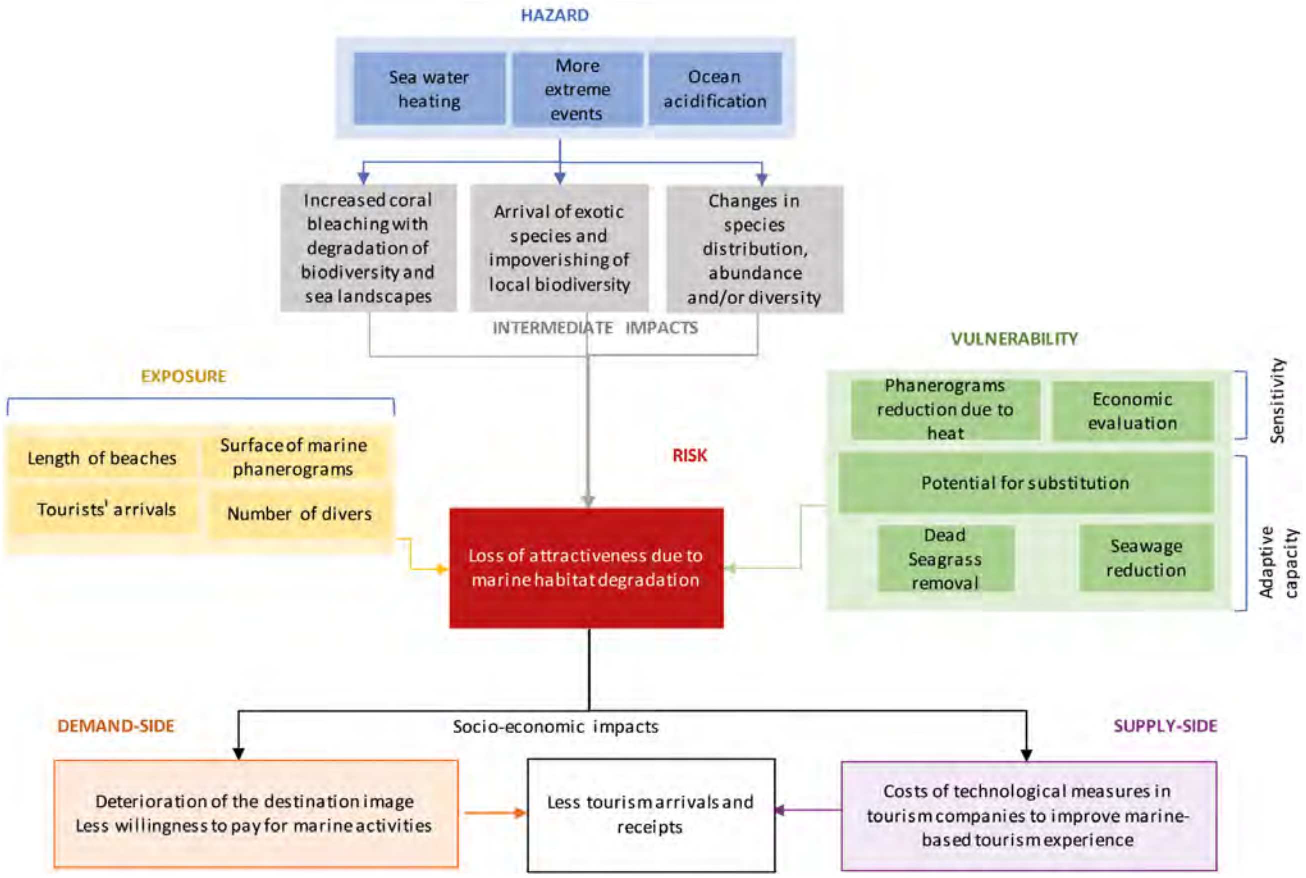


Figure 1. Loss of attractiveness of marine environments (due to loss of species and/or increase of exotic invasive species; or degradation of landscape).

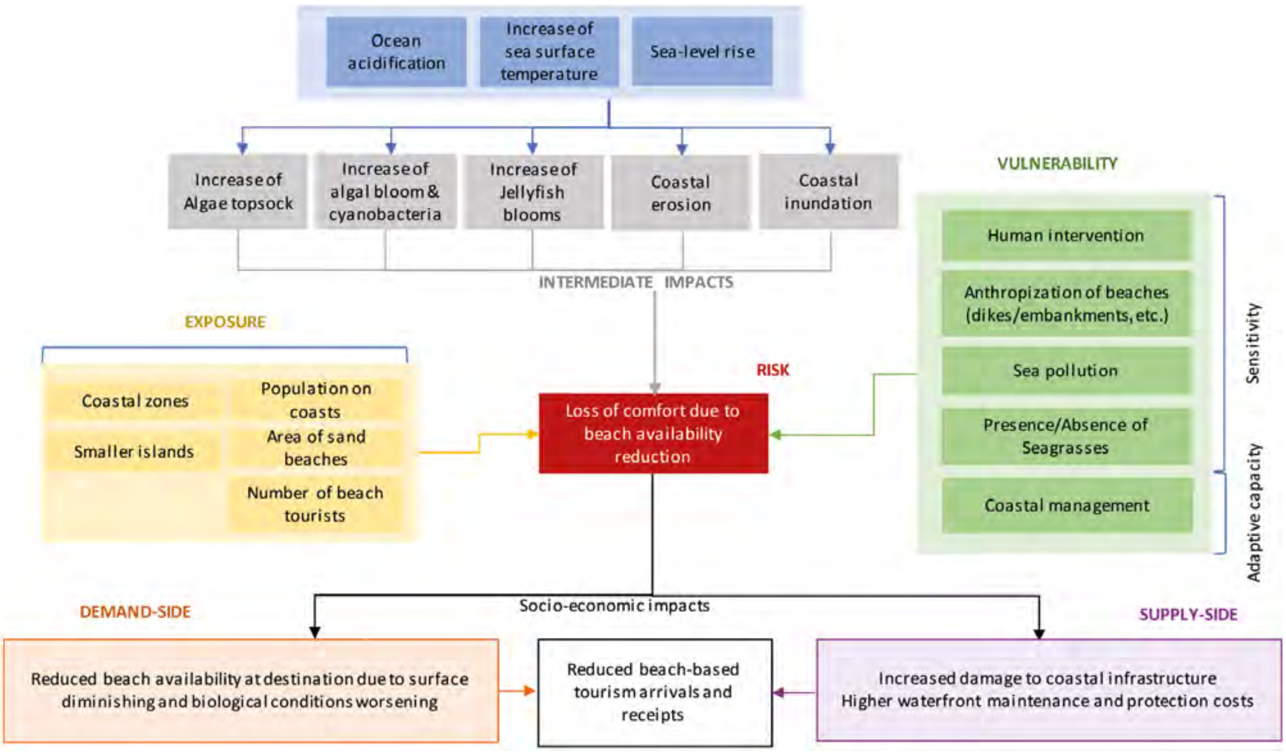


Figure 2. Loss of attractiveness and comfort due to beach availability reduction.

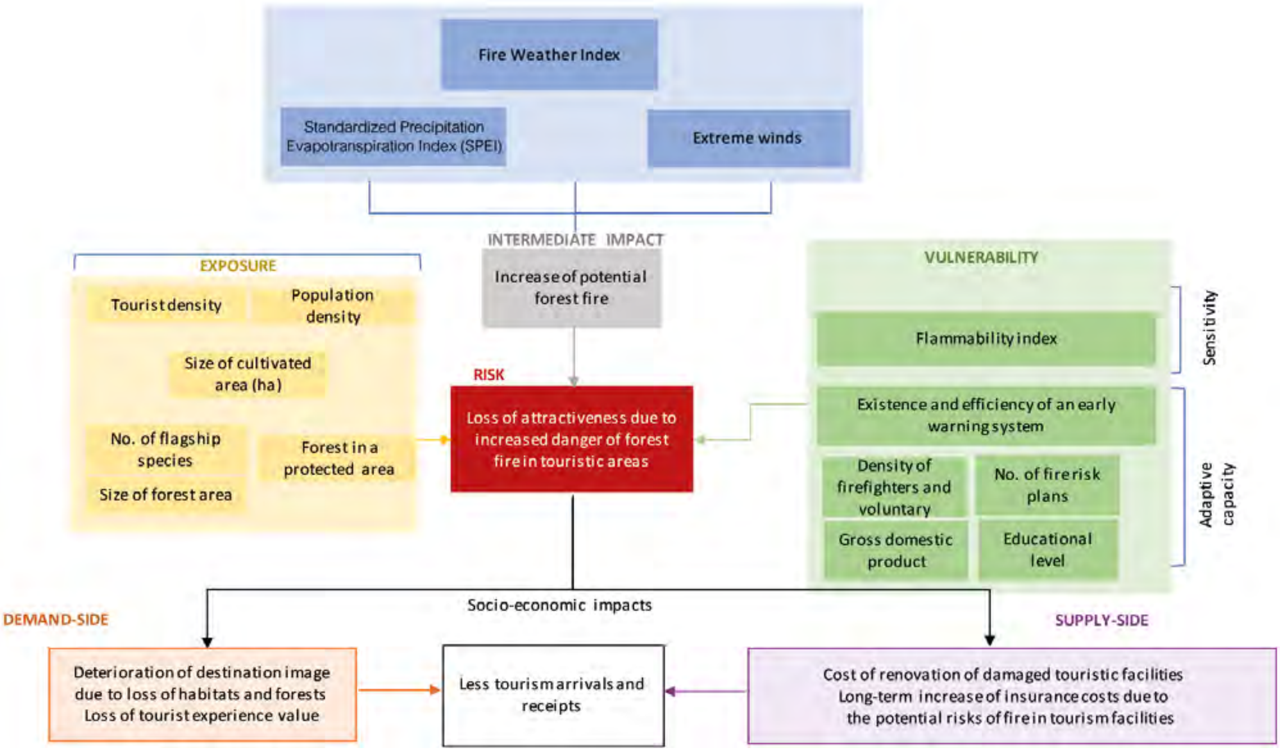


Figure 3. Loss of attractiveness due to increased danger of forest fire in tourism areas.

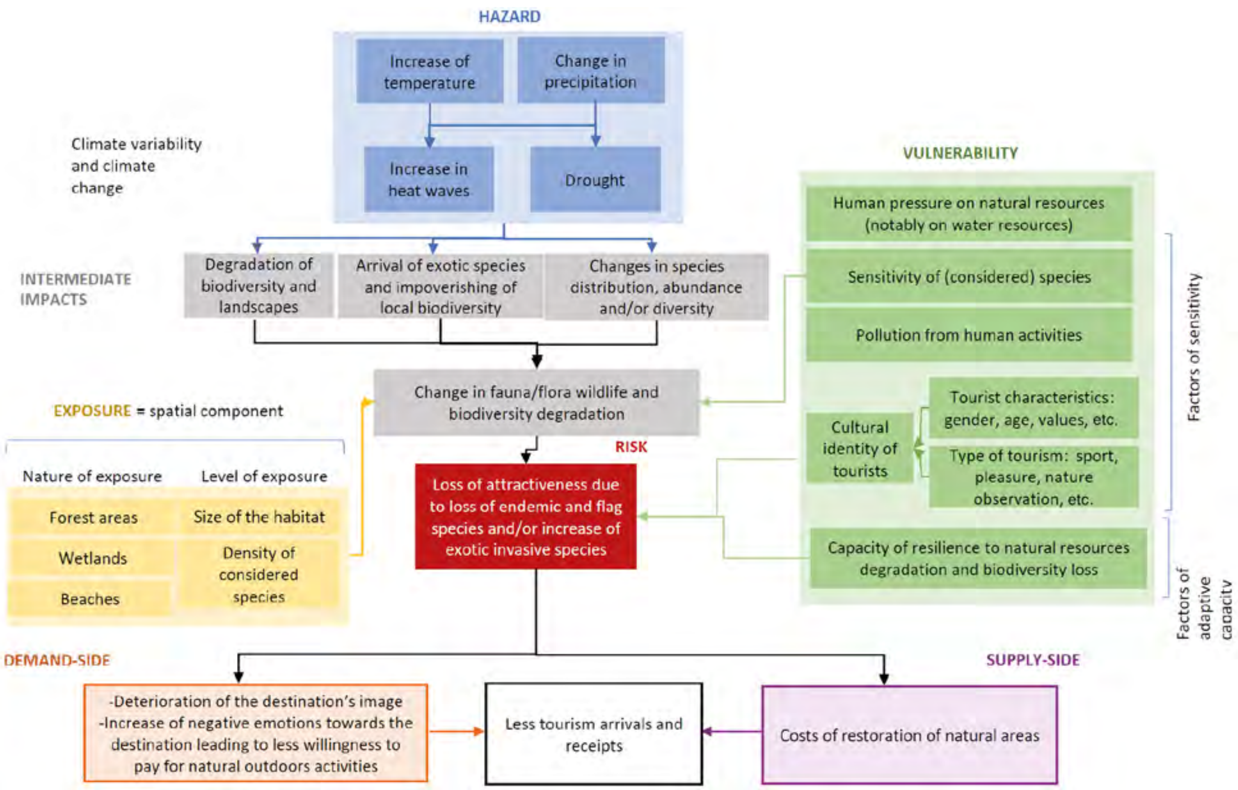


Figure 4. Loss of attractiveness of land environments (due to loss of species and/or increase of exotic invasive species; or degradation of landscape).

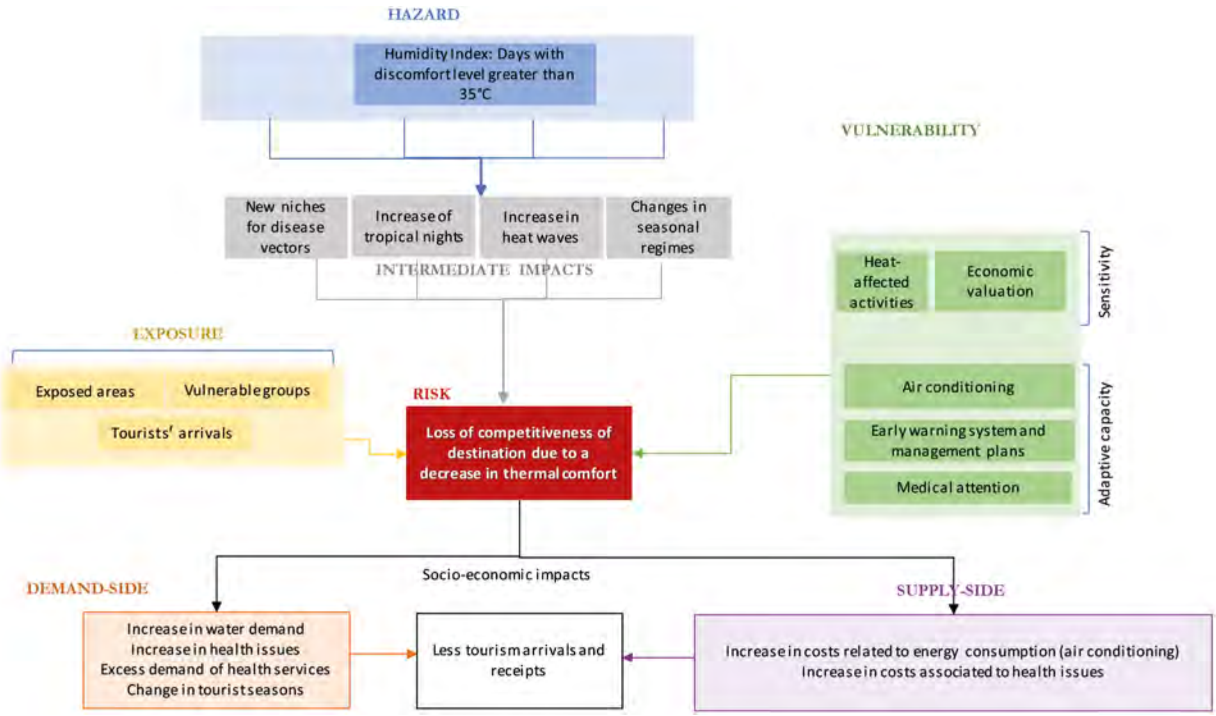


Figure 5. Loss of competitiveness due to a decrease in thermal comfort.

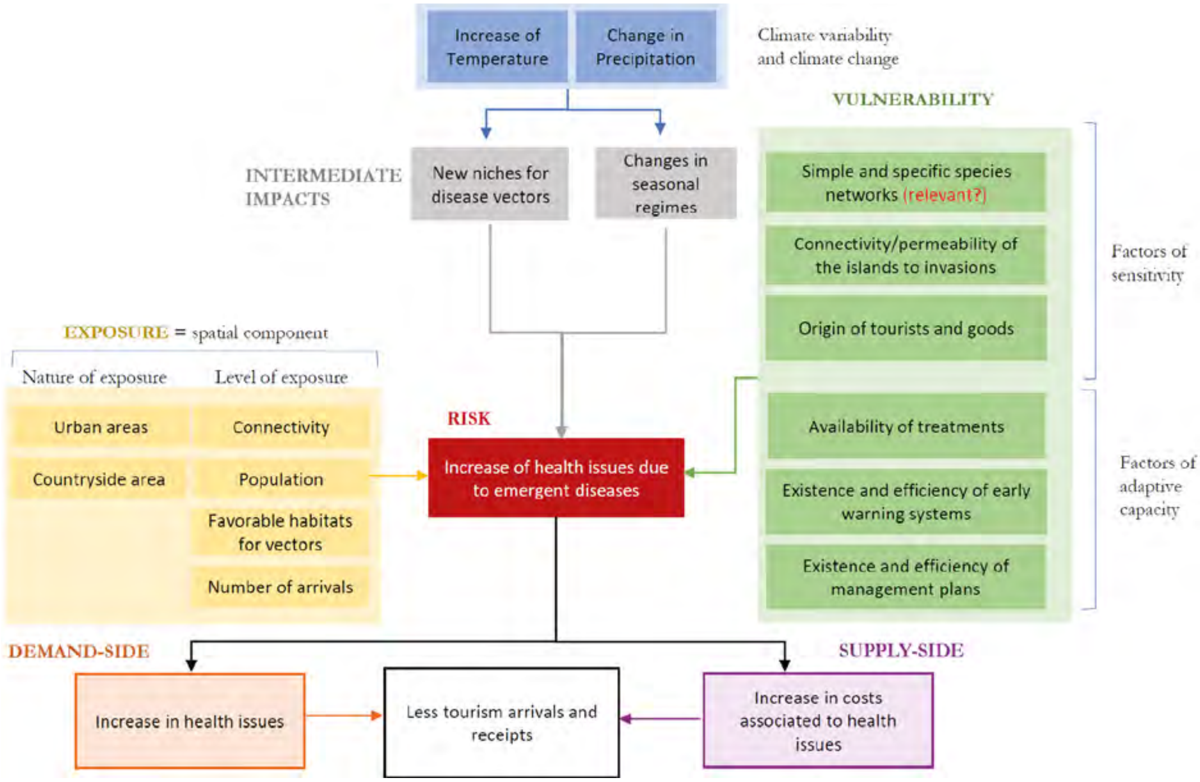


Figure 6. Increase of health issues due to emergent diseases.

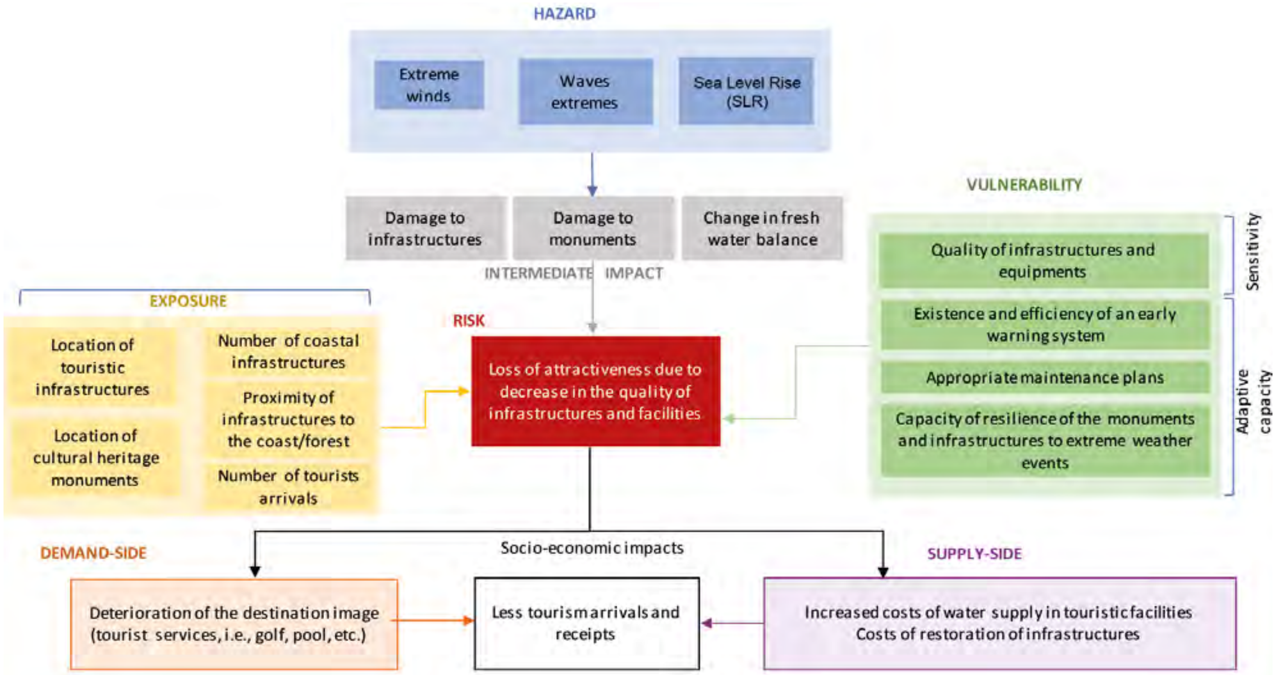


Figure 7. Increase of damages to infrastructures and facilities (accommodation, promenades, water treatment system, etc.) due to sea level rise and extreme weather conditions.

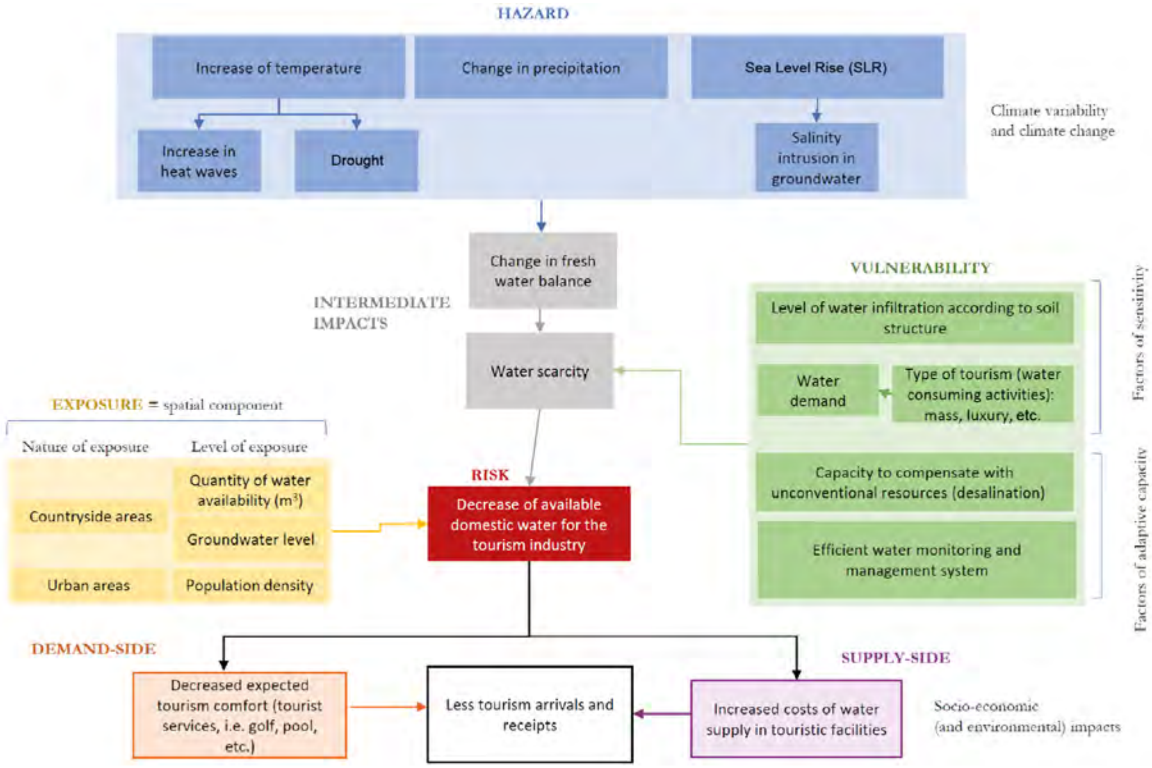


Figure 8. Decrease of available domestic water for the tourism industry.

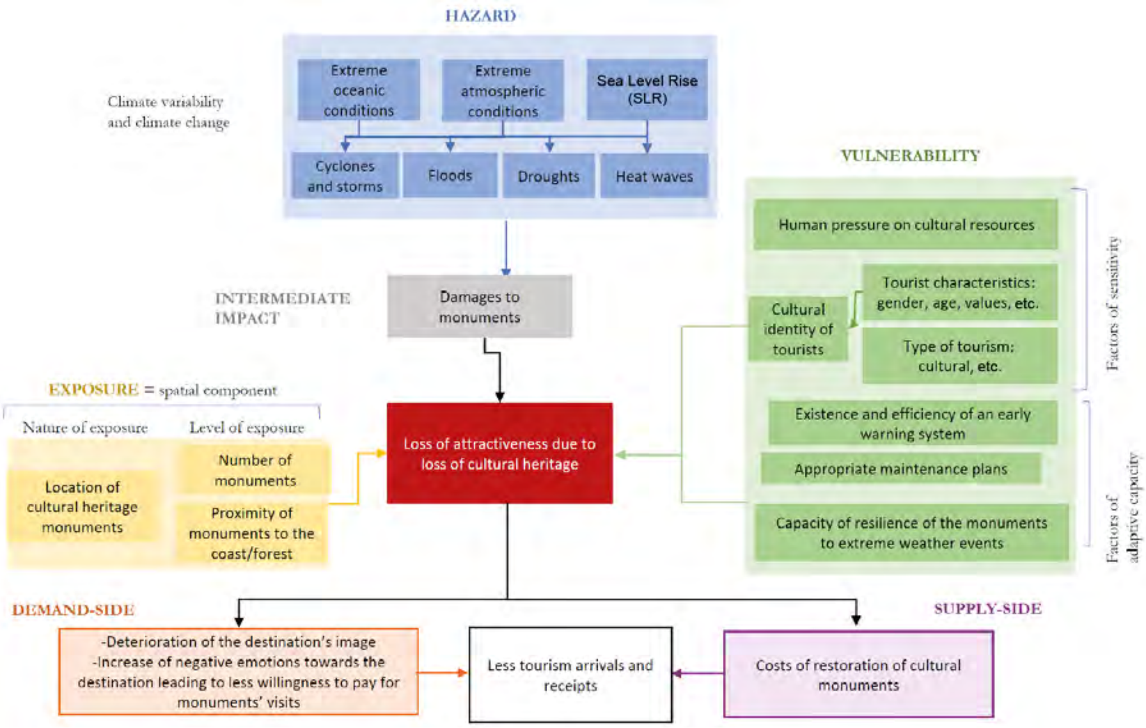


Figure 9. Loss of attractiveness due to loss of cultural heritage (monuments, gastronomy, etc.).

Appendix B: Impact Chains Analysed for the Aquaculture Sector

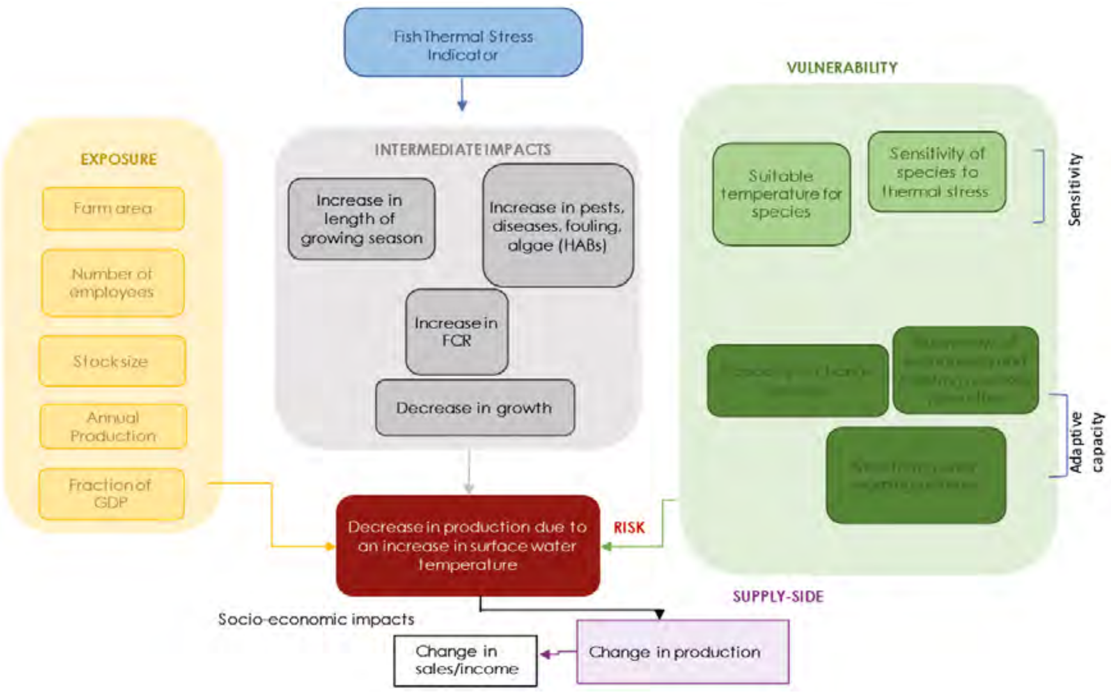


Figure 10. Decrease in production due to an increase in sea surface temperature.

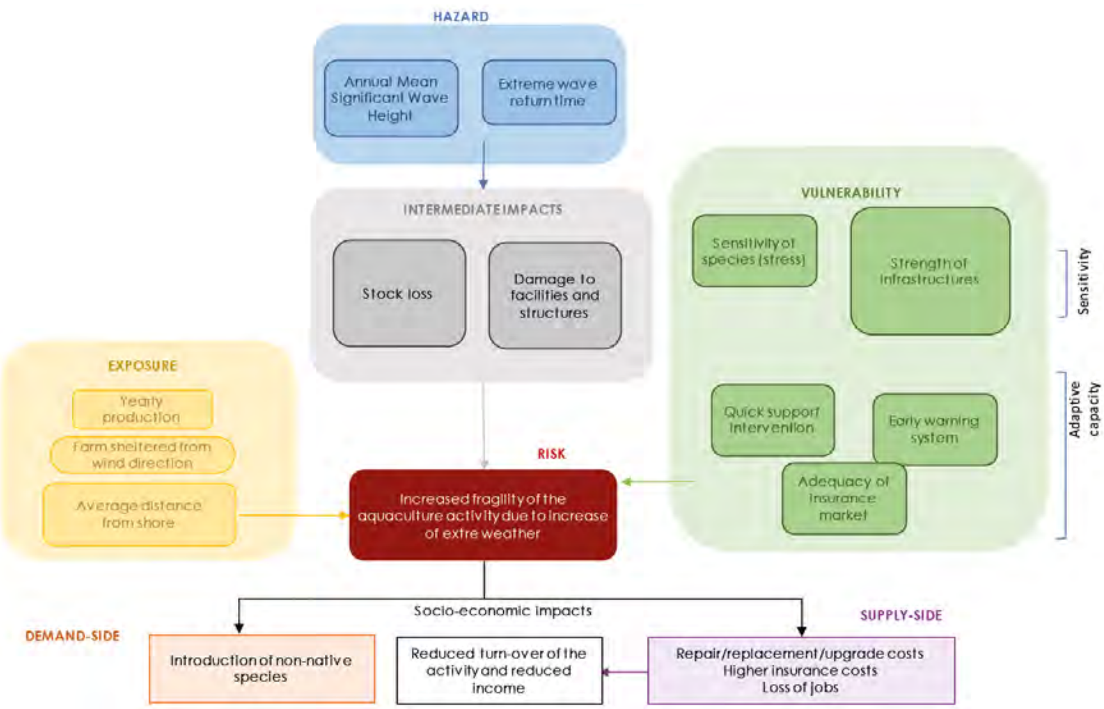


Figure 11. Increased fragility of the aquaculture activity due to increase of extre weather.

Appendix C: Impact Chains Analysed for the Energy Sector

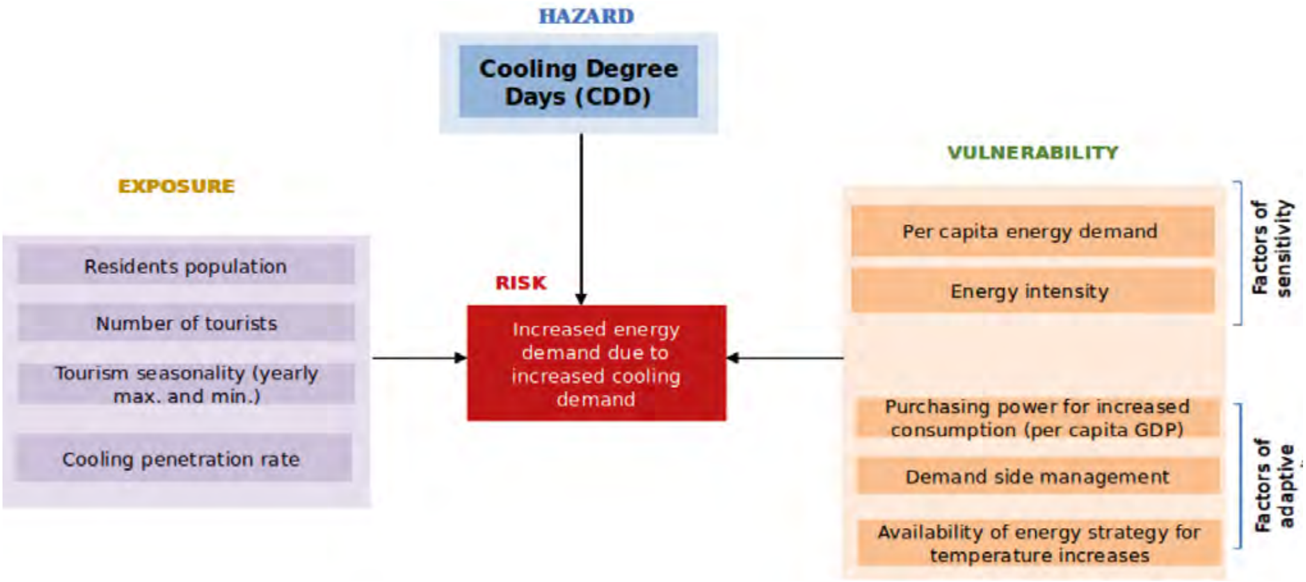


Figure 12. Risk of increased energy demand due to increased cooling demand.

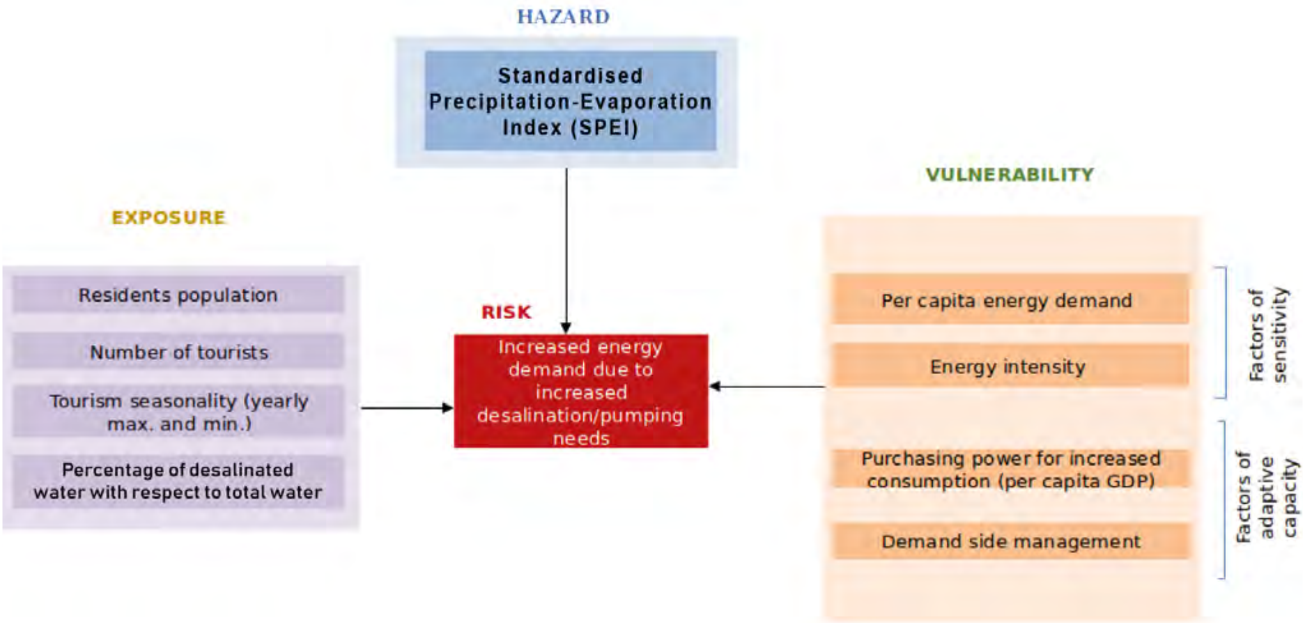


Figure 13. Risk of increased energy demand due to increased desalination/puping needs.

Appendix D: Impact Chains Analysed for the Maritime Transport Sector

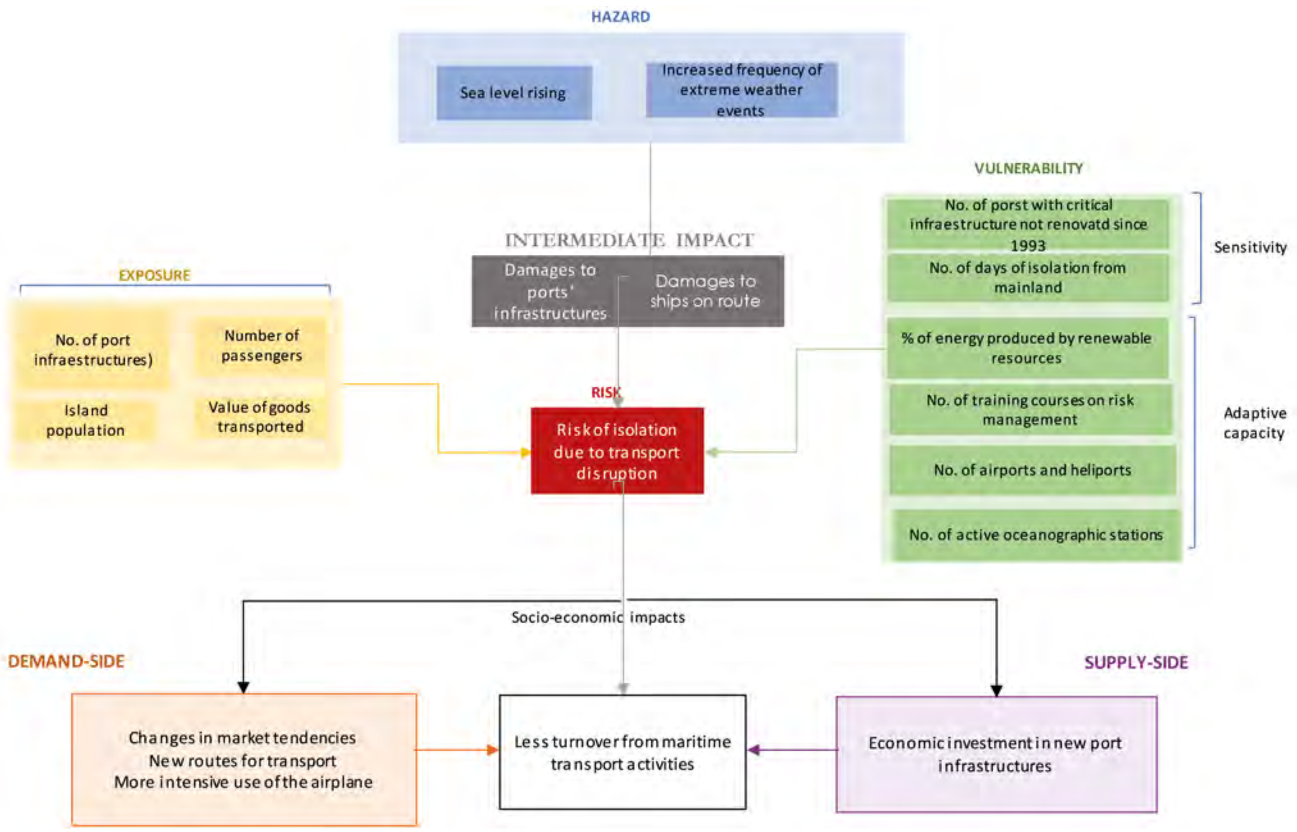


Figure 14. Risk of isolation due to transport disruption.

Appendix E: Methods for the Risk Assessment: Loss of Attractiveness due to Marine Habitat Degradation

The hierarchy tree for this decision problem was built underpinning on the impact chain presented in Appendix A. Some modifications of the original impact chain were undertaken for the sake of feasibility, although experts were encouraged to have in mind all the factors they know can affect the impact of climate change on the marine habitat services for tourism. It means that the hierarchy tree is a simplified structure of the main factors explaining the complex relationship between climate change and the ecosystem services that support tourist use of marine environments, but other factors also known by experts must be taken into account at the time of comparing the risk components between islands. This is one of the most interesting strengths of the decision processes based on expert participation and, particularly, of the multicriteria analysis used in this case (see **Figure 15**).

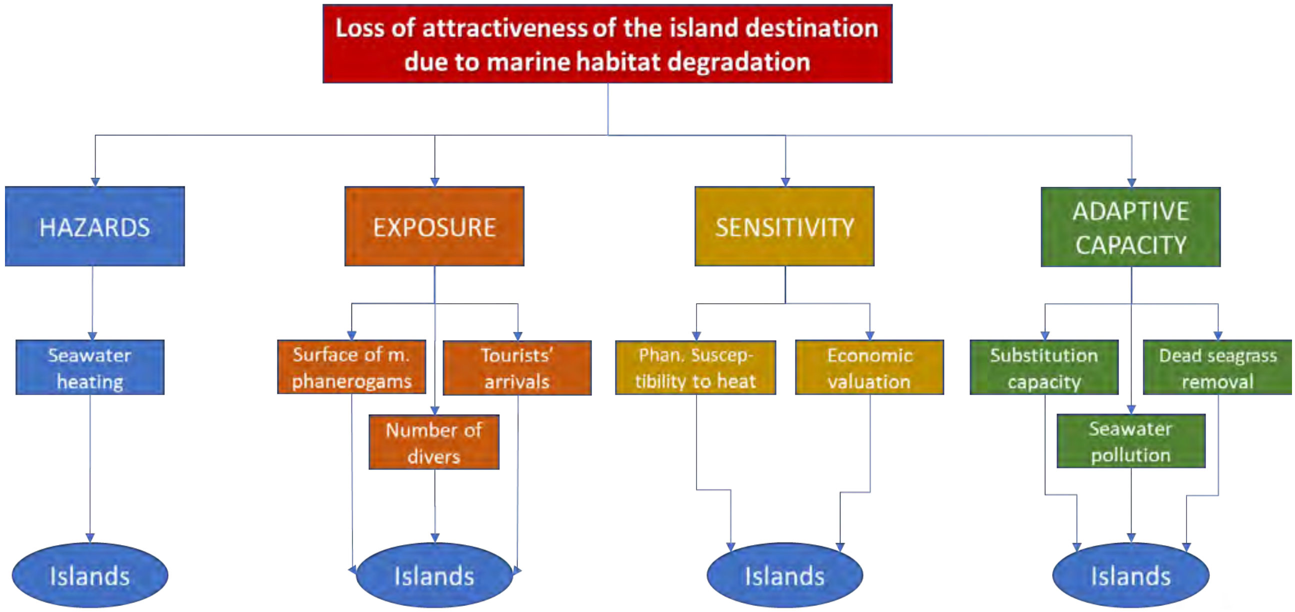


Figure 15. Hierarchy tree for marine habitats impact chain.

Hazards: Seawater heating was considered as the most relevant variable to assess changes in the conservation status of the marine habitats that provide services for coastal tourism activities. Other hazards initially considered, like acidification and storms, were finally discarded. The former because its effects on living marine organism are still under study, and the evidence is dispersed and not conclusive. The latter because in the Mediterranean Sea and the Atlantic Ocean, which surrounds the islands under study, storms are considered not so frequent and intense to not give time to marine ecosystems to recover their previous conservation status.

Regarding indicators, published research shows 25 and 26 Celsius degrees as the threshold temperatures over which seagrass meadows, the foundation species that mainly structure ecosystems in the marine habitats of reference, start to decline. The indicators used were the number of days per year with seawater temperature over 25 and 26 Celsius degrees.

Exposure: The natural and social systems potentially damaged by the selected climate hazards was decomposed into three sub-criteria, one referred to the marine environment, and the other two related to the use that tourists make of the services provided for the marine environments at the destination. These three sub-criteria were expressed through three respective indicators. One, referred to the surface of marine phanerogams that suffer from the climate stressors. Phanerogams, specially Posidonia in the Mediterranean and Cymodosea in the Atlantic, are the very foundation species organizing most of the coastal ecosystems. They provide food and shelter to many different species and keep seawater clear by absorbing sediments. Additionally, when they become damaged, seagrasses meadows deliver dead individuals that go to lay on the beaches used by tourists.

The second sub-criterion is one about the different types of direct uses that tourists make of the ecosystem services. Diving was selected to represent these uses and the selected indicator was the number of divers per year. It was assumed that other sea watching activities like snorkelling and bottom-glass boating evolve similarly than diving. Experts were also invited to consider other sea environment users potentially affected by the lack of water transparency and dead seagrass suspended in seawater like surfers, windsurfers and other active users of the marine environment. The third sub-criterion was related to the impact on most of tourists as bathers. Turbid water affects the quality of the bathing experience, which is an activity that most tourists do.

Sensitivity: This relates to the susceptibility of the phanerogam meadows to changes in seawater temperature and to the extent to which the impoverishing of seawater conditions and marine ecosystems may affect tourists' welfare. Regarding the effects of episodes of seawater heating on the integrity of seagrasses meadows, the variable selected was periods of overheating, and the indicators were the number of days per year with seawater temperature over 25 and 26 Celsius degrees. As explained above, experts were invited to take into account their experience and their knowledge about the differences between the way seagrasses behave in the real world and in the laboratory when studying the impact of water heating. With respect to the impact of the marine environmental degradation on the welfare of tourists, the indicator selected was the tourists' willingness to pay for the preservation of marine ecosystems. Thus, ecosystems' and social's susceptibility are both taken into account when comparing risks of marine environment degradation due to climate change between islands.

Adaptive capacity: This criterion was split into three sub-criteria, one referred to the substitution of marine-based activities by lesser marine habitats dependent ones, and two concerning actions to heal the marine environment like removing dead seagrasses or reducing non-treated sewage discharges (and consequently, seawater pollution). In this case, island experts were consulted about the capacity of their reference destination to address these adaptation actions using a 1-4 scale, where 1 represented a very poor management capacity and 4 expressed a full capacity to deal with it.

Results and islands' ranking

The table below shows the final results of the operationalization process. In particular, it summarizes the global weights of the sub-criteria and the criteria as well as the global score of the risk for each island; thus, islands can be compared not just globally, but also across the set of the sub-criteria and the criteria being considered to estimate the aggregated risk (see **Table 1**).

Table 1. Final scores and islands' ranking (under RCP8.5 distant future).

Criteria	Sub-criteria	Balearic	Canary	Cyprus	Malta	Sardinia
Hazards	Seawater heating RCP8.5 (2081-2100)	0.018 *(8.0%)*	0.004 *(2.2%)*	0.054 *(23.6%)*	0.025 *(12.7%)*	0.025 *(14.7%)*
Exposure	Surface of marine phanerogams	0.034	0.002	0.004	0.009	0.022
	Number of divers	0.009	0.005	0.001	0.002	0.002
	Tourists' arrivals	0.013	0.013	0.002	0.001	0.006
	Total	0.056 *(25.0%)*	0.020 *(11.0%)*	0.007 *(3.1%)*	0.012 *(6.1%)*	0.029 *(17.1%)*
Sensitivity	Phanerogams' susceptibility to heat	0.072	0.072	0.008	0.024	0.024
	Economic valuation	0.003	0.027	0.004	0.006	0.010
	Total	0.075 *(33.5%)*	0.099 *(54.7%)*	0.012 *(5.2%)*	0.030 *(15.2%)*	0.034 *(20.0%)*
Adaptive capacity	Products substitution	0.034	0.034	0.086	0.060	0.016
	Seagrass removal	0.020	0.002	0.007	0.007	0.003
	Sea water pollution	0.021	0.021	0.063	0.063	0.063
	Total	0.079 *(35.3%)*	0.058 *(32.0%)*	0.155 *(67.7%)*	0.130 *(66.0%)*	0.082 *(48.2%)*
Total		0.224	0.181	0.229	0.197	0.170
Rank		2	4	1	3	5

Note: Total contribution of the criterion to the final score of the island in parenthesis.

The relative risk for marine habitat-based tourism demand due to the heating of seawaters surrounding the European islands is determined by the combination of three different factors already reflected in the marine habitat impact chain: the intensity and lasting of periods of seawater heating, the susceptibility of the marine habitats and tourism activities based on it to the heating process and the changes in the habitat, respectively, and the capacities of the respective islands' societies to reinforce natural and social systems' resilience to seawater heating and its ecosystem impacts.

Based on the available indicators and on their own knowledge, the experts' evaluation of the complex relationships between seawater heating, habitats transformation and the response of the tourism system depicts a big picture featured by the following results:

- From the perspective of the intensity of the hazard, threats diminish from east to west. Effectively, episodes of water heating threating the integrity of marine ecosystems will be much more relevant throughout the eastern Mediterranean and will become softer as moving western.
- From the perspective of the susceptibility of the marine foundation species to seawater heating, western Mediterranean hosts the most vulnerable phanerogam communities, as genetically they are not ready to face increasing water temperature variability at the rhythm climate change is powering. As a result, this risk factor decays from western to east.
- Other relevant factors determining the relative risk faced by each island are related to the management capacity of other hazards, different than seawater heating, also degrading marine habitats (i.e., the current relevance of marine habitat-based tourism and the capacity of the local tourism system to provide competitive alternatives giving value to other, not marine-based natural and cultural tourist attractions). Those capacities are unevenly distributed across the islands, basically depending on the level of development of their respective environment management and tourism management subsystems.

Some characteristics of the risk ranking provided by experts, and consequently, the final scores are:

- Cyprus leads the rank of risk due to, in addition to the greater seawater heating, its experiencing ecological disruptive processes related to its closeness to the Red Sea, strongly attracting exotic species with high capacity to destabilise the marine ecosystems.
- On the other extreme, Sicily is the island exhibiting a lesser risk mainly due to the fact that it holds a more balanced distribution of the indicators expressive of the range of factors determining the risk.
- The Canary Islands hold a relatively low risk mainly due to their expected low level of seawater heating; their higher weakness consists of the magnitude of the tourism system exposed to the potential risk.
- The Balearic Islands are the most exposed islands. In addition, RCP8.5 in the distant future shows a progress in heating relatively higher than other islands, meaning a strong threat for their relatively susceptible Posidonia meadows.
- Malta holds a relative low risk mainly due to its low exposition to the risk and the potential of alternative, non-marine-habitat-based, tourist products.

In the eastern Mediterranean, the impact of seawater heating on the seagrass meadows (and on the marine habitat as a whole) not only depends on the physiological response of the plants affected by heating, but also on the response of the system as a whole. On the eastern shore of the Mediterranean, a strong increase in herbivorous species from the Red Sea has been observed, which cross the Suez Canal and have settled near the continental and insular coastal areas. Posidonia meadows have been found to be part of their diet.

Appendix F: Methods for the Risk Assessment: Loss of Competitiveness due to a Decrease in Thermal Comfort

The hierarchy tree for this decision problem was built underpinning on the impact chain elements. Some refinements were necessary regarding the indicators (at sub-criteria level) that were to be used for comparing the islands (see **Figure 16**).

Hazards: For the AHP method, thermal sensation was considered as the most relevant indicator to assess changes in the thermal comfort of tourists while staying at their destination, as it is a concept that combines temperature and humidity. Thus, it is the only sub-criterion of the Hazard criterion. Moreover, the humidity index (Humidex) (Masterton and Richardson, 1979) was selected as the most appropriate metric for thermal sensation. The metric is an equivalent temperature that express the temperature perceived by people (i.e., the temperature that the human body would feel), given the actual air temperature and relative humidity.

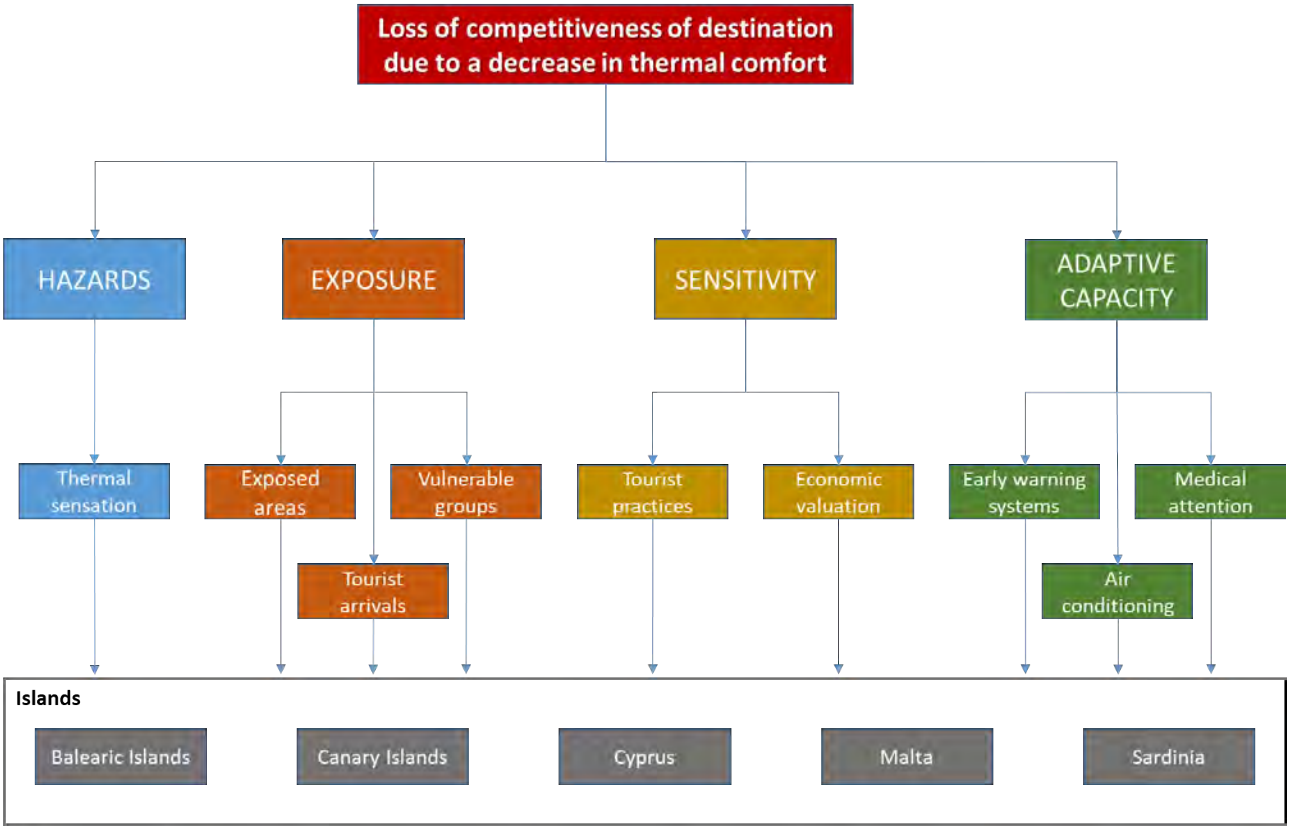


Figure 16. Hierarchy tree for thermal comfort impact chain.

Exposure: This criterion was decomposed into sub-criteria relating to three indicators. The first indicator relates to the exposure of tourists to heatwaves. The measure of the indicator combines the percentage of an island prone to heatwaves and the percentage of the tourist accommodations and facilities located in those areas prone to heatwaves. It is necessary to factor in both these aspects of exposure in order to allow for a better comparison of islands. For example, if an island has a small area that is prone to heatwaves with the majority of tourists frequenting that small area, then the combination of the two factors will play a role when comparing, for instance, an island that has large areas prone to heatwaves, but with tourists frequenting places outside these areas, since the overall exposure will be different. Specifically, it was decided to assign a weight of 75% to percentage of an island prone to heatwaves and the remaining 25% to the percentage of tourist accommodations and facilities located in heatwave-prone areas. The second indicator deals with the number of tourist arrivals during the hottest months. The indicator is represented by the percentage of tourists that visit an island between the months of May and September averaged over the last five years. Finally, the third indicator concerns vulnerable groups of tourists who have the highest risk of being affected by heatwaves. Literature confirms that under-6s and over-65s are the most vulnerable age groups; however, the statistical services of the islands homogeneously provide data for the under-14 and over-65 age groups. For this indicator, two values were computed:

1. The number of tourists visiting an island that were under 14 years of age during the months of May and September over the total number of tourists visiting during the same period, averaged over the last five years.
2. The number of tourists visiting an island that were over 65 years of age during the months of May and September over the total number of tourists visiting during the same period, averaged over the last five years.

For purpose of combining the two values and adjusting the change to age groups, it was decided to apply a ratio of 15:85 in order to emphasize the proportion of over-65s (85%) to the proportion of under-14s (15%).

Sensitivity: This relates to the susceptibility of tourists and is broken down into sub-criteria pertaining to two indicators. The first indicator involves tourist activities. The effect of heatwaves on tourist activities varies greatly. For example, a tourist sunbathing at a beach will not feel the effects of a heatwave to the same degree as a tourist that is trekking. Different destinations have different rates of tourists practicing activities incompatible with heatwaves events. So, this indicator aims at catching these differences. More specifically, this indicator is a measure of the percentage of visitors who state that they practice activities not compatible with heatwave events. The second indicator concerns the economic valuation of heatwaves from the perspective of tourists. In the case of a heatwave event, all tourists will suffer from thermal discomfort to a certain degree. Hence, the indicator represents their willingness to avoid this discomfort as expressed in monetary terms. Therefore, it is measured by how much money tourists are willing to pay to avoid a heatwave during their vacation time.

Adaptive capacity: This reveals the potential to face the hazards by reducing the level of exposure and/or increasing the resilience of the tourism system through providing information, adopting proper technology, supplying alternative activities, and improving medical attention. This criterion is split into sub-criteria concerning three indicators. The first indicator deals with early warning systems. Setting up a proper early warning system can help tourists and service providers to plan effective responses to heatwaves, making them less distressing and reducing the destination's vulnerability. Hence, this indicator is measured with a score representing the quality of early warning systems in place and advisement of options for tourists. The second indicator involves air conditioning. Air conditioning is the most effective technology used to combat extreme heat. Therefore, the indicator uses the percentage of hotel accommodations and tourist facilities offering air conditioning systems as a measure of the capacity of the destination to cope with this hazard. The final indicator concerns the care and medical attention (such as in the case of heatstroke or similar) available on an island that may be necessary to help reduce pain or avoid casualties due to diseases related to heatwaves. Consequently, the number of hospital beds available on an island per 100,000 potential users, both residents and tourists, is taken as the measure of this indicator.

Results and islands' ranking

The table below shows the final results of the operationalization process. In particular, it summarizes the global weights of the sub-criteria and the criteria as well as the global score of the risk for each island; thus, islands can be compared not just globally but also across the set of the sub-criteria and the criteria being considered to estimate the aggregated risk (see **Table 2**).

Cyprus is at most risk of loss of competitiveness due to a decrease in thermal comfort in all four scenarios, as it is ranked the highest in all cases. This is mainly attributed to the fact that the number of days with a heatwave is predicted to increase greatly both in the near and distant future. In addition, the island's tourist accommodations and facilities are located in areas most prone to heatwaves, and these are visited by many tourists during the months of May to September. Cyprus also scores the highest in sensitivity and average in adaptive capacity.

The Balearic Islands and Malta are ranked second and third, respectively, with regards to the risk of loss of competitiveness. However, their overall scores are very close: 0.199 for the Balearic Islands and 0.1970 for Malta in the RCP8.5 distant future scenario. They score relatively high in exposure and sensitivity (the most important criteria for the risk) and average in hazard and adaptive capacity.

Sardinia and the Canary Islands are the lowest at risk of loss of competitiveness. Even though Sardinia scores the highest for exposure, it has a low score for sensitivity (which contributes most to the risk) and average scores for hazard and adaptive capacity. On the other hand, the Canary Islands has a low score for hazard and exposure, but relatively high for sensitivity and adaptive capacity.

Table 2. Final scores and islands' ranking (under RCP8.5 distant future).

Criteria	Sub-criteria	Balearic	Canary	Cyprus	Malta	Sardinia
Hazards	Humidex RCP8.5 (2081-2100)	0.024 *(12.1%)*	0.008 *(4.6%)*	0.088 *(34.6%)*	0.023 *(11.7%)*	0.023 *(13.1%)*
Exposure	Exposed areas	0.007	0.002	0.007	0.007	0.007
	Vulnerable groups	0.007	0.017	0.016	0.017	0.038
	Tourists' arrivals	0.050	0.008	0.029	0.018	0.065
	Total	*0.064 (32.2%)*	*0.027 (15.5%)*	*0.053 (20.9%)*	*0.042 (21.3%)*	*0.110 (62.9%)*
Sensitivity	Heat-sensitive activities	0.074	0.073	0.074	0.074	0.012
	Economic valuation	0.004	0.004	0.015	0.028	0.010
	Total	*0.079 (39.7%)*	*0.078 (44.8%)*	*0.089 (35.0%)*	*0.103 (52.3%)*	*0.021 (12.0%)*
Adaptive capacity	Early-warming systems	0.007	0.007	0.007	0.007	0.003
	Air conditioning	0.011	0.048	0.011	0.021	0.012
	Medical attention	0.014	0.006	0.005	0.002	0.005
	Total	*0.032 (16.1%)*	*0.061 (35.1%)*	*0.024 (9.4%)*	*0.030 (15.2%)*	*0.020 (11.4%)*
Total		**0.199**	**0.174**	**0.254**	**0.197**	**0.175**
Rank		**2**	**5**	**1**	**3**	**4**

Note: Total contribution of the criterion to the final score of the island in parenthesis.

Appendix G: Methods for the Risk Assessment: Loss of Attractiveness due to Increased Danger of Forest Fires in Touristic Areas

The methodology represented here is one of the first attempts to quantify the levels of fire risk under future climate for several Mediterranean islands. Impact chains are not exhaustive, but rather describe the common understanding, supported by studies and expertise, of cause-effect relationships of the investigated phenomena. Indeed, the impact chains have the aim of reducing the complexity in order to make simpler the risk assessment and lower the time and economic resources necessary.

But, the more a modelling approach aspires to capture complexity and dynamics, the more it requires training and learning to be used. On the one hand, this approach can hardly describe the complexity of fire phenomenon in the environment and society and the chain dynamics triggered by climate change; on the other hand, this approach could provide regional and local administrators, engaged in institutional paths aimed at adapting their territories to climate change, the basic operating elements for defining a scientific knowledge framework that is preparatory to the planning of the most appropriate measures of adaptation. Indeed, the design of specific adaptation measures depends on local climatic scenarios, environmental characteristics, geographic location, and socio-economic constraints.

The reliability of the results depends on a number of elements, such as:

- Quality of the input data (including resolutions and completeness).
- Uncertainties consideration.
- Normalization.
- Weighting of the indicators and limits to expert judgement.
- Participatory approach.

Quality of data: many socio-economic, including demographics, income, education, labor for the impact chains are required at the provincial or municipal administrative levels. Many indicators for several islands were available only at NUTS2 or NUTS3 administrative levels; however, to obtain clear information about risk and thus define where to allocate resource to mitigate it or perform adaptation finer resolutions (at municipal or local scales) these indicators are needed.

Uncertainties due to the different calculation of the indicators

The availability of the appropriate datasets for the calculation of FWI is often a limiting factor. This is often true when it comes to the exploitation of the model projections outputs that are usually provided as daily values, while the FWI system requires higher temporal resolution variables. Thus, a proxy variable combination needs to be selected (Bedia *et al.*, 2013), though the optimum combinations have not been tested for the model datasets used in this study. Therefore, the possible biases in Atlantic FWI values derived from the proxy combination (daily Tmax and RHmin, and local noon wind) cannot be estimated. A multi-model ensemble approach is important, as the inter-model variability can mask the proxy bias that may result from the FWI sensitivity to minimum relative humidity and/or maximum temperature.

Concerning the weighting of the indicators, we applied a participatory approach involving stakeholders and experts through one-to-one meetings and developed and effective, informed and shared process of recognition of the most relevant indicators and subsequent attribution of the individual weights. This approach ensures robustness in the analysis and reduction of any conflicts, as the result of full sharing and acceptance of both the methodology and product results.

This approach has several strength points. As said above, it is accessible as well as easy to use and to implement, and it provides useful inputs for the identification and priorities of intervention and the preparation of adaptation measures. Also, this methodology allows the possibility to compare different realities based on appropriate indicators. On the other hand, among the weak points we can recognize the limited availability of data concerning sensitivity and adaptive capacity, and thus the need to use proxy indicators, and the relative and not absolute significance of the risk results ("red" is more vulnerable than "green" but not "red" is highly vulnerable). Regarding the participatory approach, a wide range of stakeholders was involved in the co-design process ranging from climate modelers and island focal points inside the consortium to fire risk experts. It is difficult to evaluate the overall approach and to which extent its implementation will contribute to the adaptation knowledge quality (usability, usefulness, etc.) (see **Figure 17**).

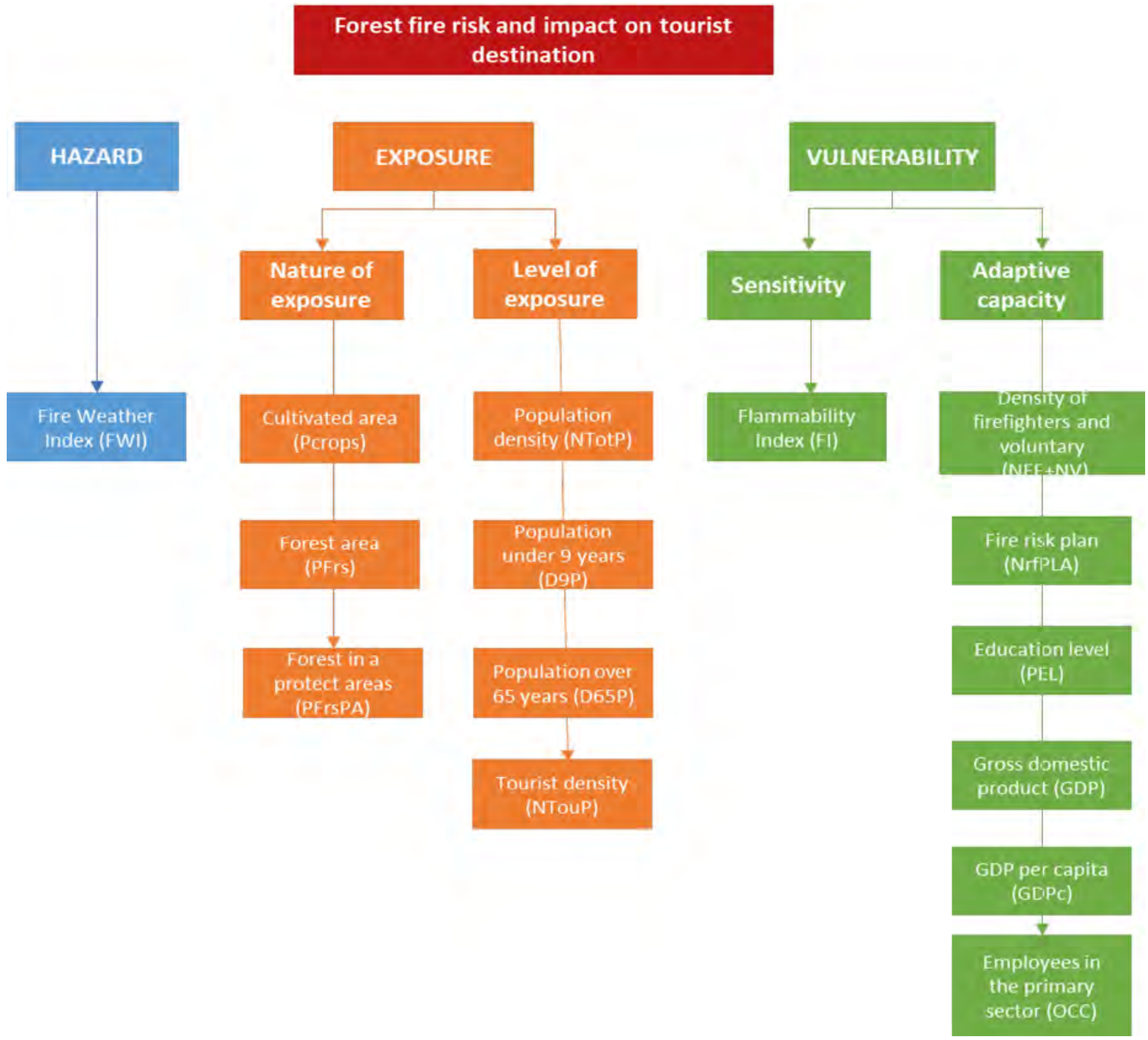


Figure 17. Hierarchy tree forest fires risk analysis.

Comparative analysis

Hazard

The main findings are:

- Scores for fire danger increase as we move from west to east and from north to south, with the exception of Malta, which is much smaller, and the selected grid cells are mostly influenced by maritime conditions.
- Under RCP2.6, it seems that the fire danger returns to the present conditions towards the end of the century, apart from Crete which score will increase from medium to high, even under this RCP.
- Under RCP8.5, the increase is much more prominent, ranging from 22% to 46%, with the highest values for Corsica, Sardinia and Sicily, which implies that under this scenario at the end of the century, the western and central Mediterranean will be more affected (see **Figures 18, 19 and 20**).

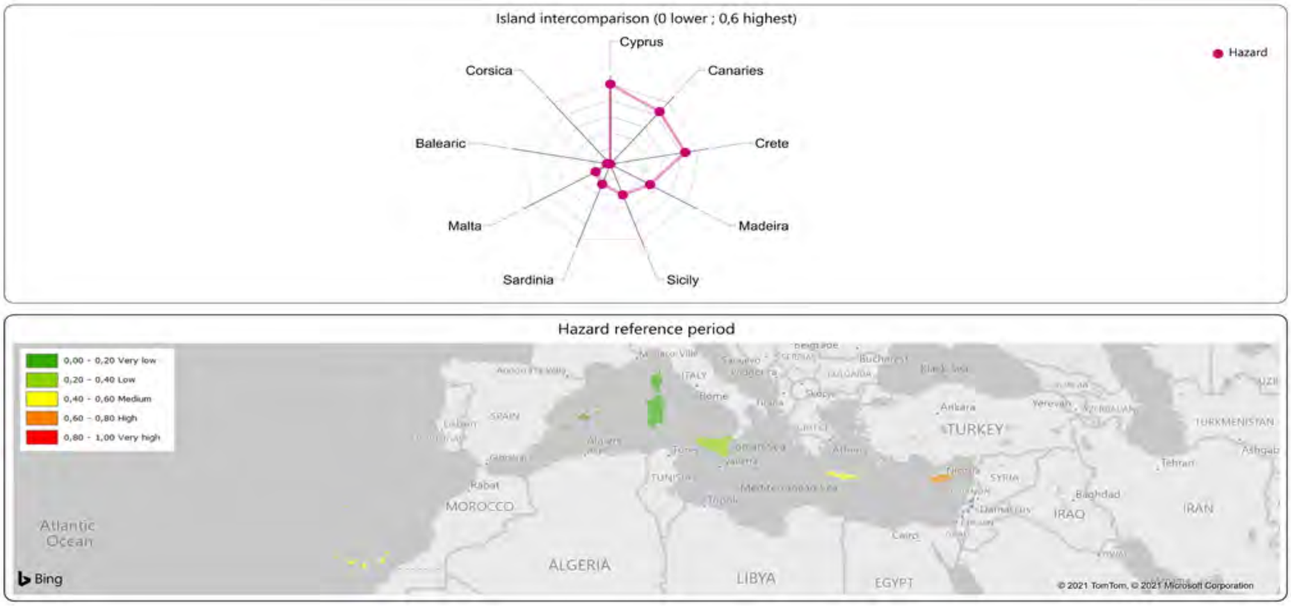


Figure 18. Hazard score (Fire Weather Index) per island for the reference period (1986-2005).

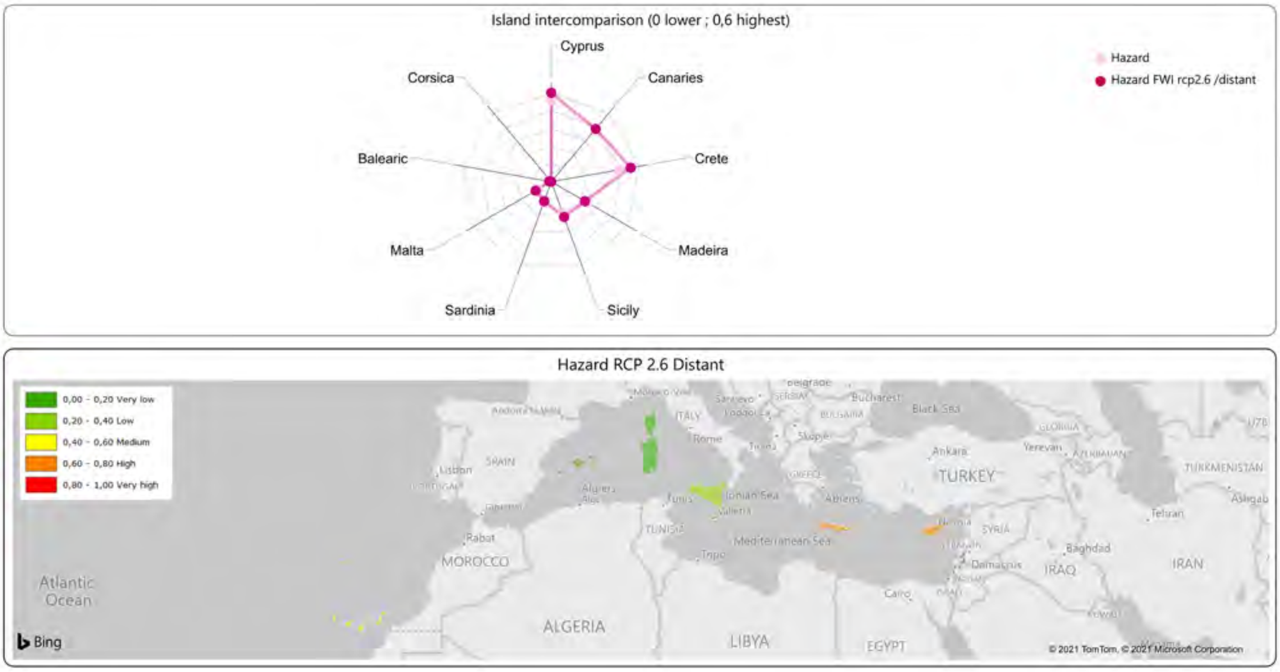


Figure 19. Hazard score (Fire Weather Index) per island at the end of the century (2081-2100) under RCP2.6 (Ambitious Mitigation Policies).

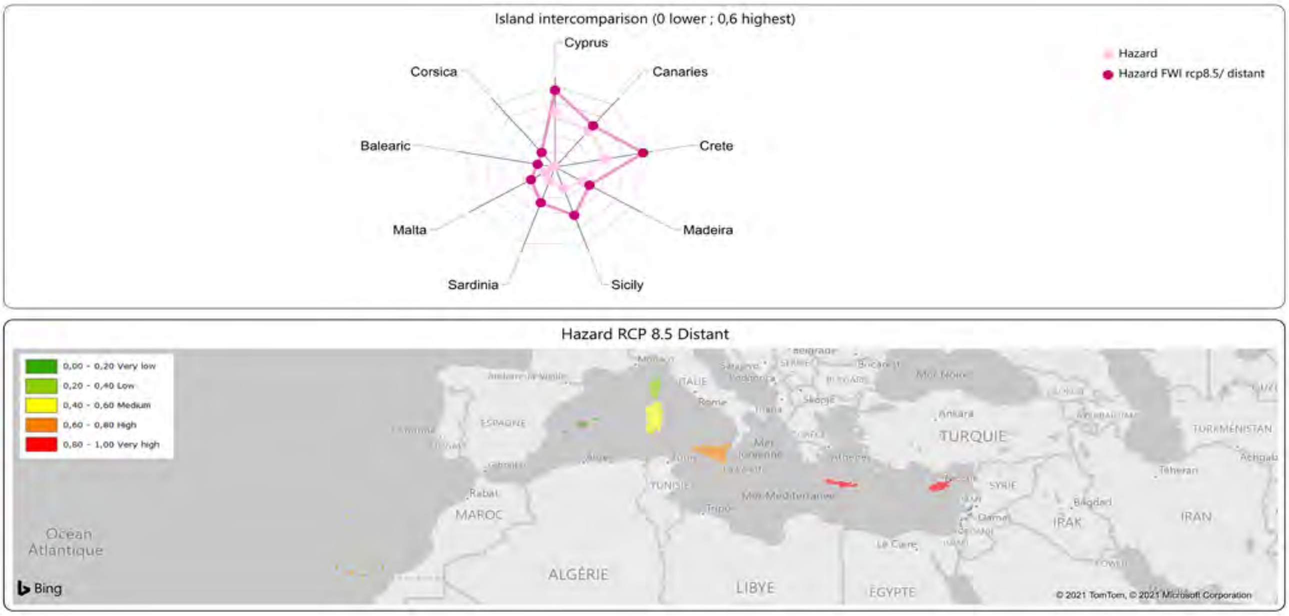


Figure 20. Hazard score (Fire Weather Index) at the end of the century (2081-2100) under RCP8.5 (Business as usual).

Exposure

The results show that:

- Atlantic Islands (Madeira and Canary Islands) are more exposed than Mediterranean Islands (from low to medium score). We can see an increase as we move from north to south in the Mediterranean area.
- Atlantics Islands higher scores are mainly explained by the level of exposure rather than the nature of exposure, which is quite similar across islands, except for Malta, whose rate is very low.
- The nature of exposure varies across EU Islands despite of their homogeneous score:
  – Corsica has the highest score for forest areas followed by Madeira and Canary Islands. These two last ones have the highest score of forest belonging to protected areas. We can find a significant proportion of cultivated areas in other Islands namely: Sicily, Sardinia, Balearic Islands, Crete and Cyprus.
- The level of exposure for Canary Islands and Madeira is particularly important because of the high scores for each of the 4 considered indicators: population density, population over 65 years, population under 9 years and tourist density (see **Figures 21, 22 and 23**).

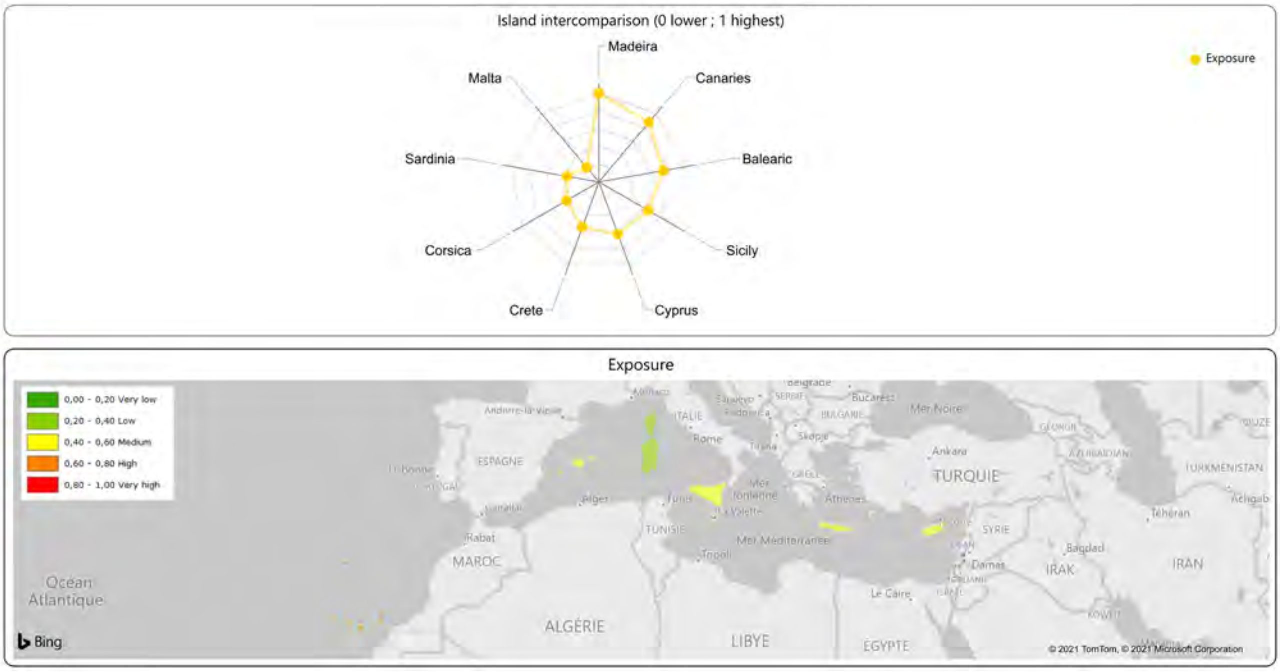


Figure 21. Exposure score (current period) per island.

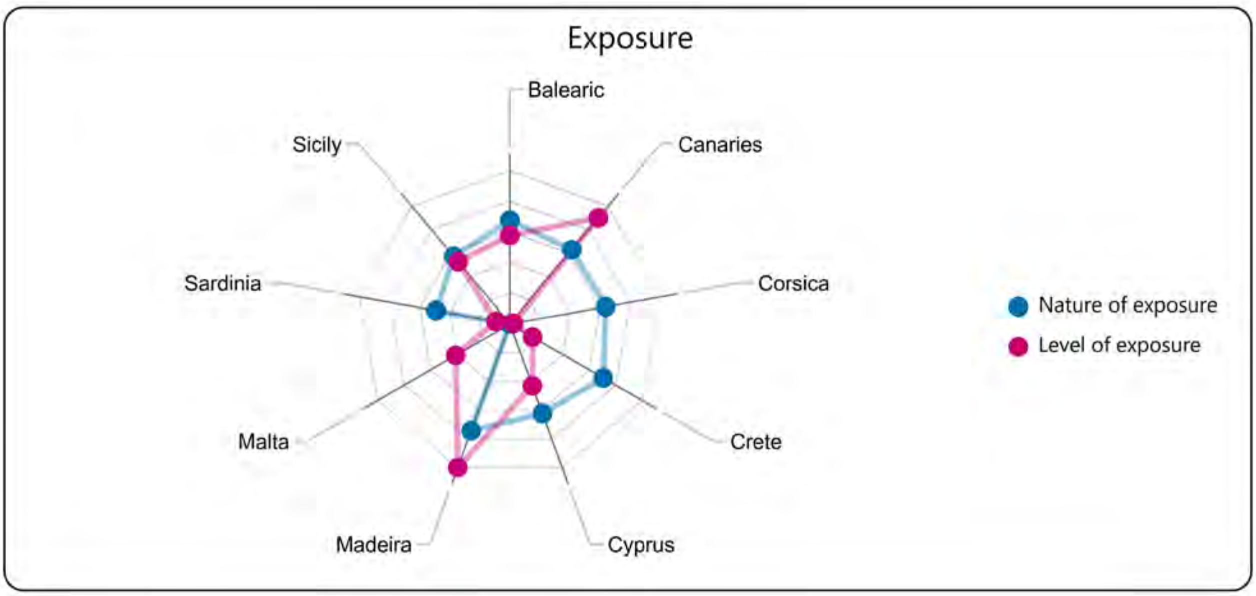


Figure 22. Subcomponents of exposure and related score (current period) per island.

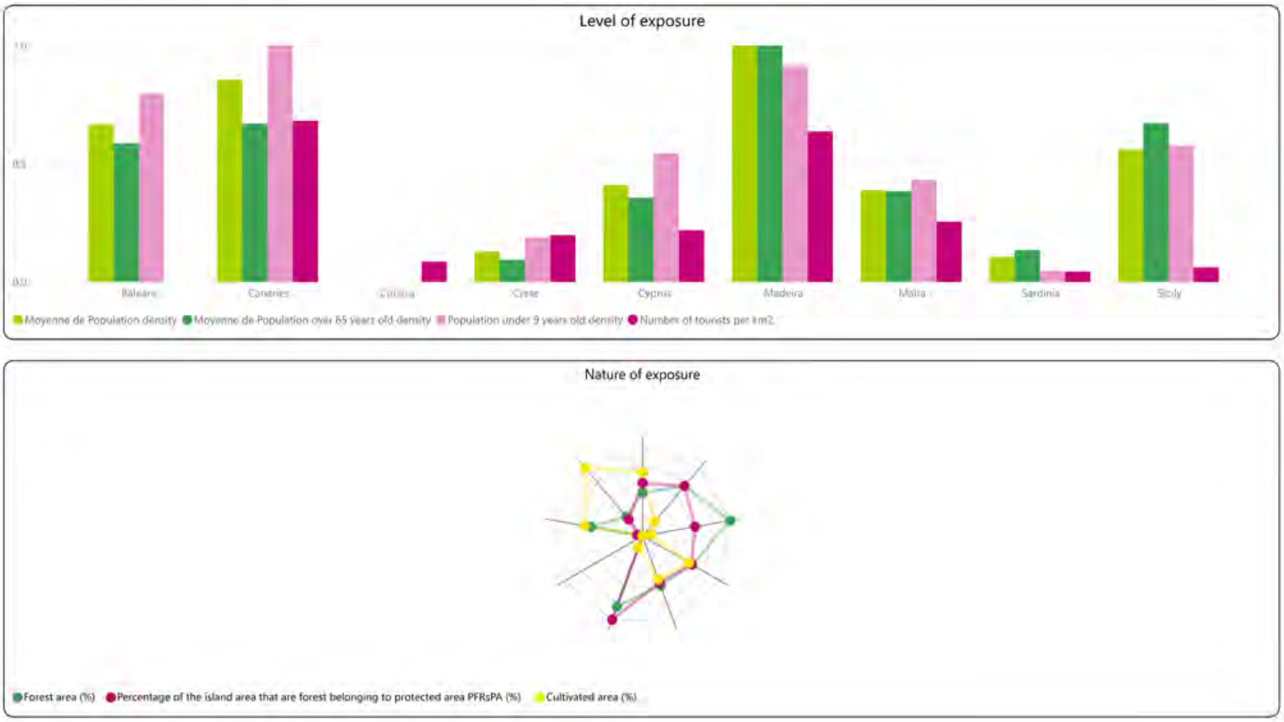


Figure 23. Breakdown by exposure subcomponent.

Vulnerability

The main findings are:

- Results show large disparity across EU Islands in terms of vulnerability. The vulnerability score for Corsica is very high followed by Sardinia (high), Madeira, Balearic Islands, Cyprus and Crete. Malta, Canary Islands and Sicilia scores are low.
- Breakdown by component highlights a quite homogeneous score for adaptative capacity, whereas sensitivity score (Flammability Index) is very different from an island to another.
- Not surprisingly for the flammability index, Corsica and Sardinia have the highest score and Malta, Sicilia and Canary Islands the lowest one.
- Looking at the adaptative capacity subcomponent, despite of the quite homogeneous scores, factors of influence are quite different among the islands:
  - High score for employees in the primary sector, apart from Sardinia and Sicily; scores for density of firefighters and volunteers are important for all the islands except for Cyprus.
  - GDP per capita and level of education are the most heterogeneous factors of influence; GDP per capita score is very high for Crete and very low for Corsica, Malta and Balearic Islands.
  - Scores for education level is important for Cyprus and low for Madeira, Malta and Corsica (see **Figures 24, 25 and 26**).

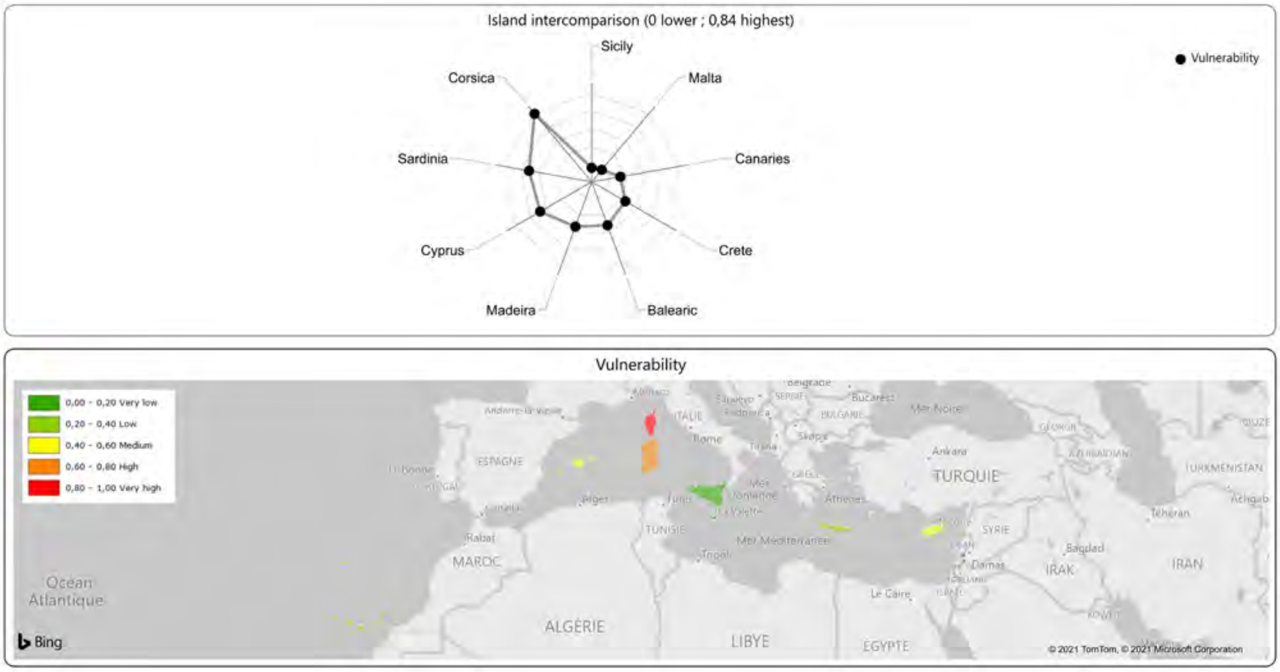


Figure 24. Vulnerability score per island.

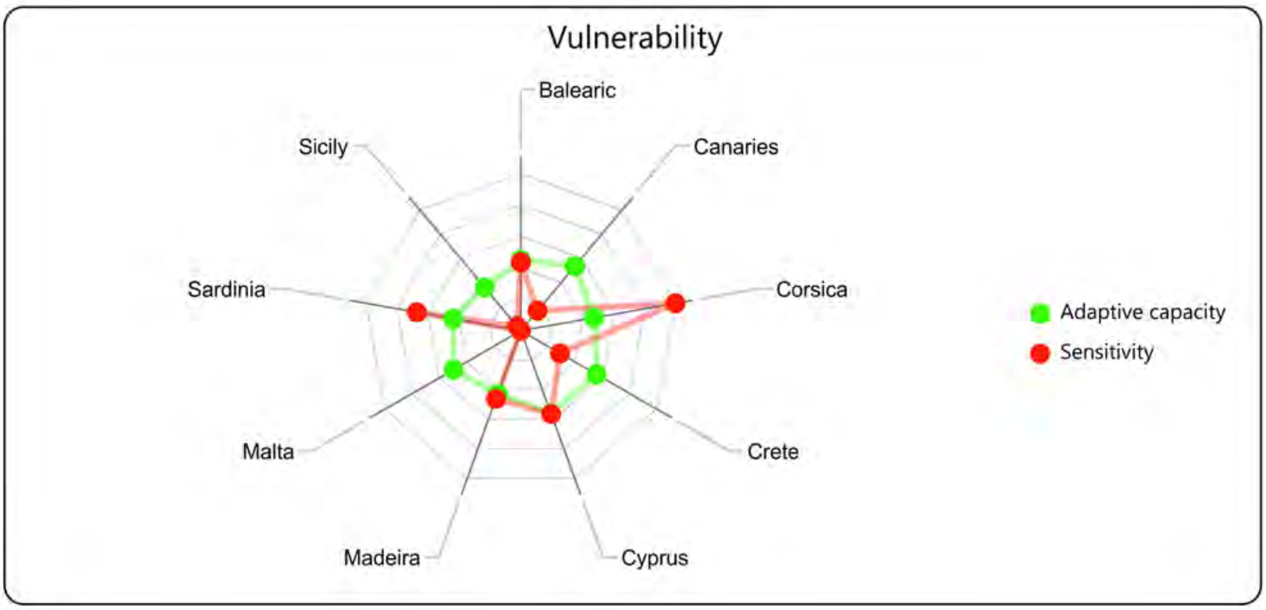


Figure 25. Subcomponents of vulnerability and related score (current period) per island.

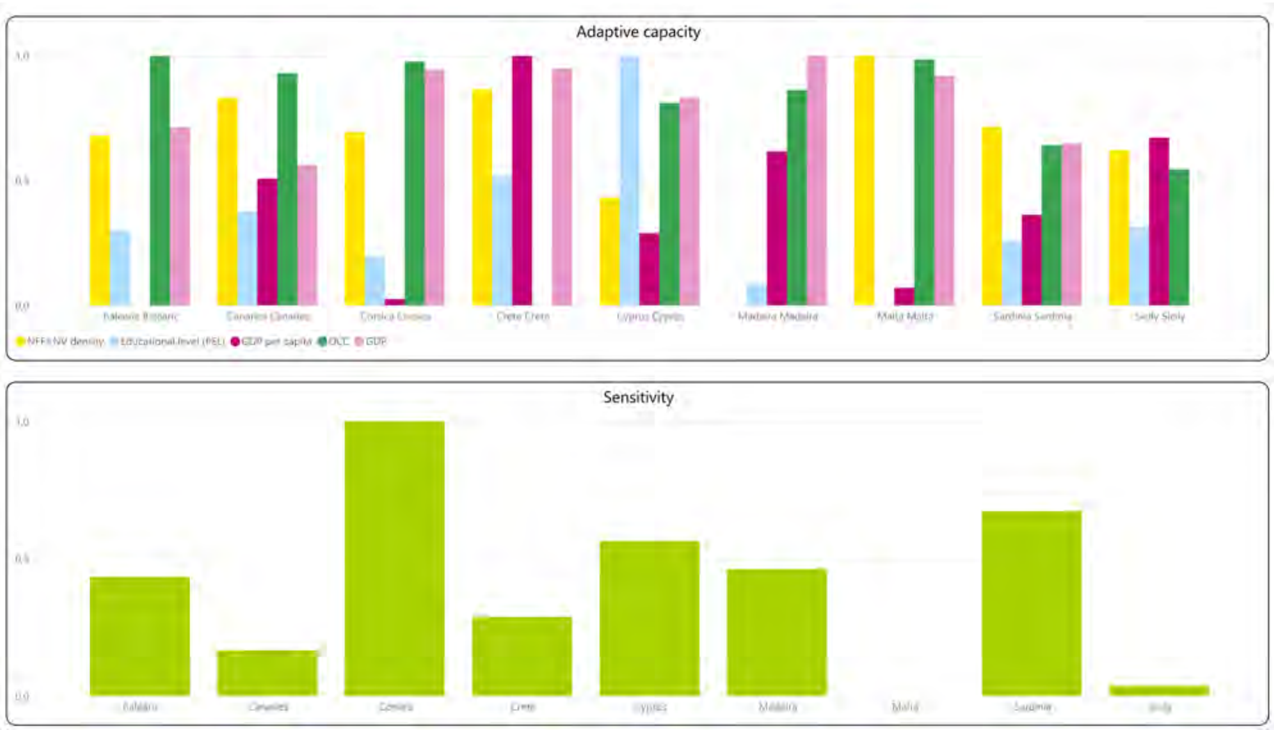


Figure 26. Details and scores of the two subcomponents (adaptive capacity and sensitivity) per island.

Risk

For the reference period, the overall risk is medium for Atlantic Islands (Madeira and Canary Islands) and eastern Mediterranean Islands (Crete and Cyprus). Risk for other islands is low and very low for Malta. Looking at the breakdown of the risk, the structure is quite similar for 3 groups:

- Madeira, Canary Islands, Sicilia and Balearic Islands: Predominance of exposure.
- Component (around 50% of the score).
- Crete and Cyprus: Predominance of the hazard component (around 40% of the score).
- Corsica and Sardinia: Predominance of the vulnerability component (around 60-70%).
- Only Malta has a quite balanced distribution across the components.

In this exercise, only the hazard component is changing in the future. In the near future, whatever the considered RCP, the risk increases only for Cyprus from medium to high. While the risk remains stable with the RCP2.6 in the distant future for all islands apart from Cyprus, there is an increase from very low to low for Malta and from low to medium for Balearic Islands, Corsica and Sardinia with RCP8.5, Even under this RCP8.5 risk remains constant for Canary Islands and Madeira (medium) and Sicily (low) (see **Figures 27, 28, 29, 30 and 31**).

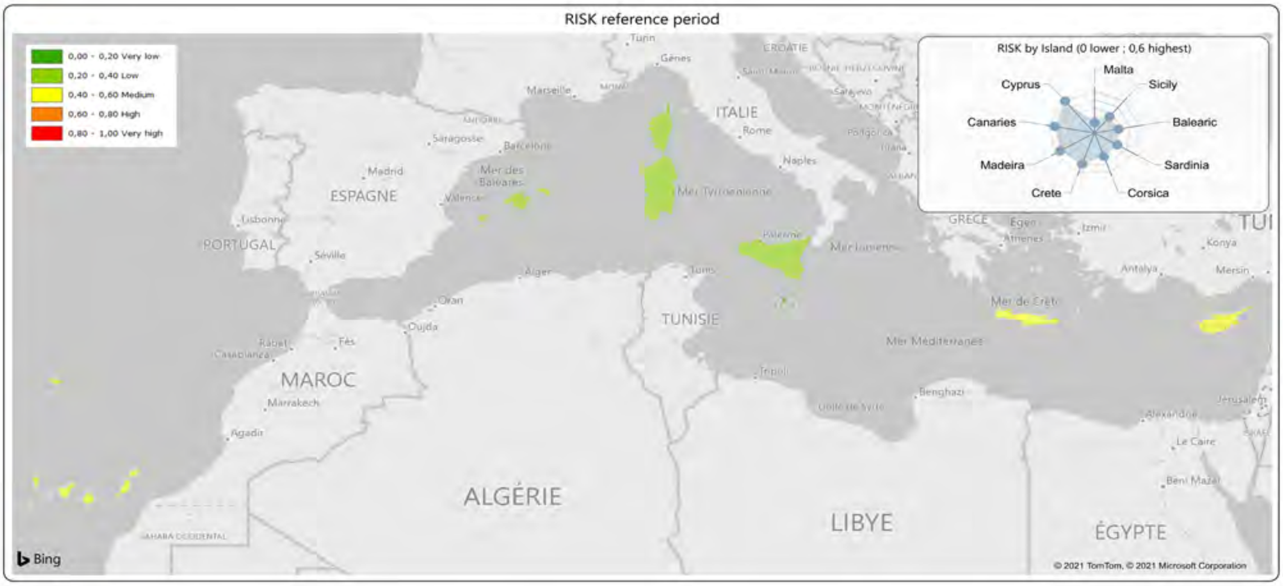


Figure 27. Risk score per island for the reference period (1986-2005)

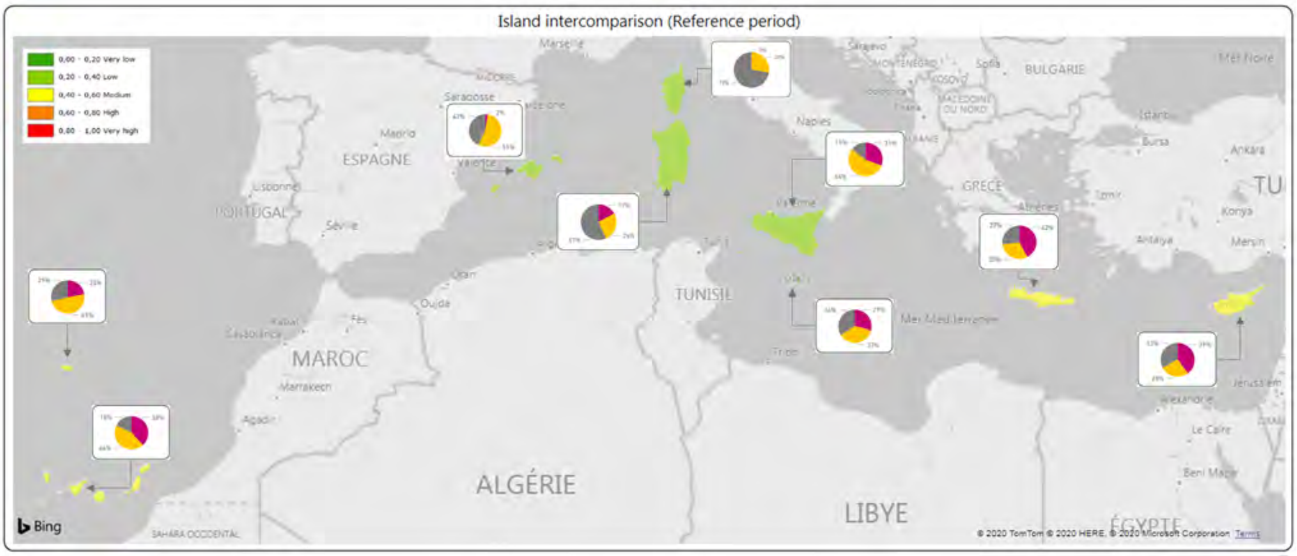


Figure 28. Risk breakdown by island for the reference period (1986-2005)

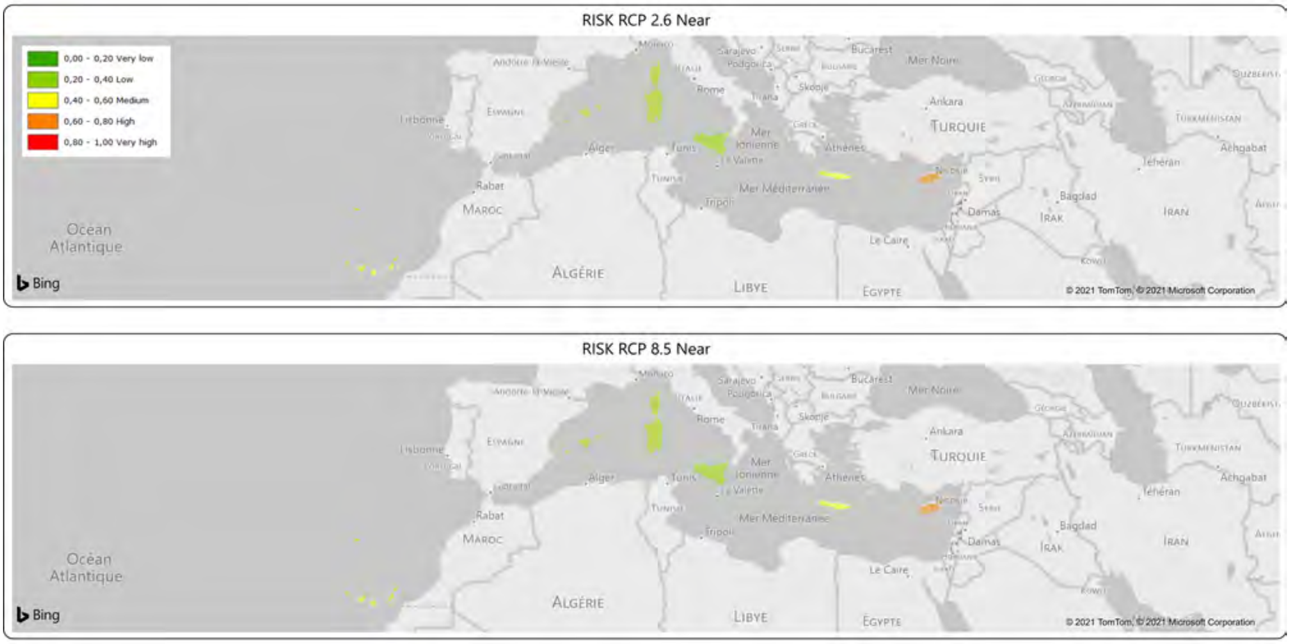


Figure 29. Risk score per island in the near future (2046-2065) under RCP2.6 (Ambitious Mitigation Policies) and RCP8.5 (Business as usual)

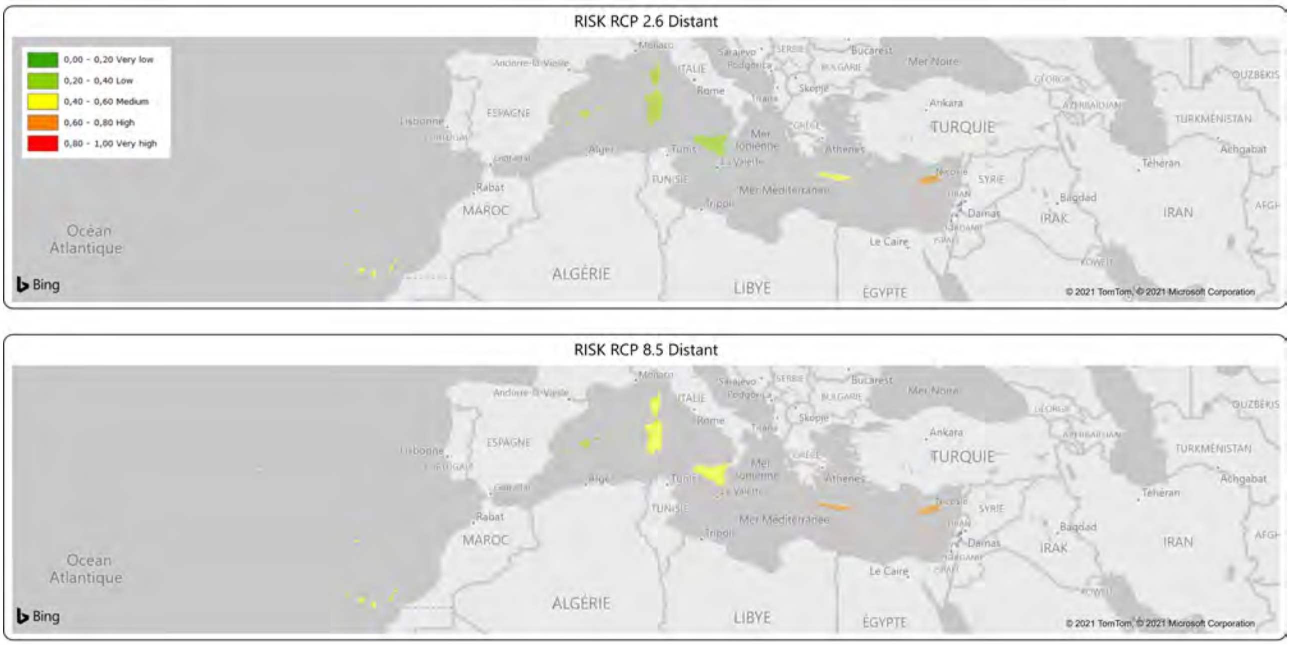


Figure 30. Risk score per island at the end in the distant future (2081-2100) under RCP2.6 (Ambitious Mitigation Policies) and RCP8.5 (Business as usual)

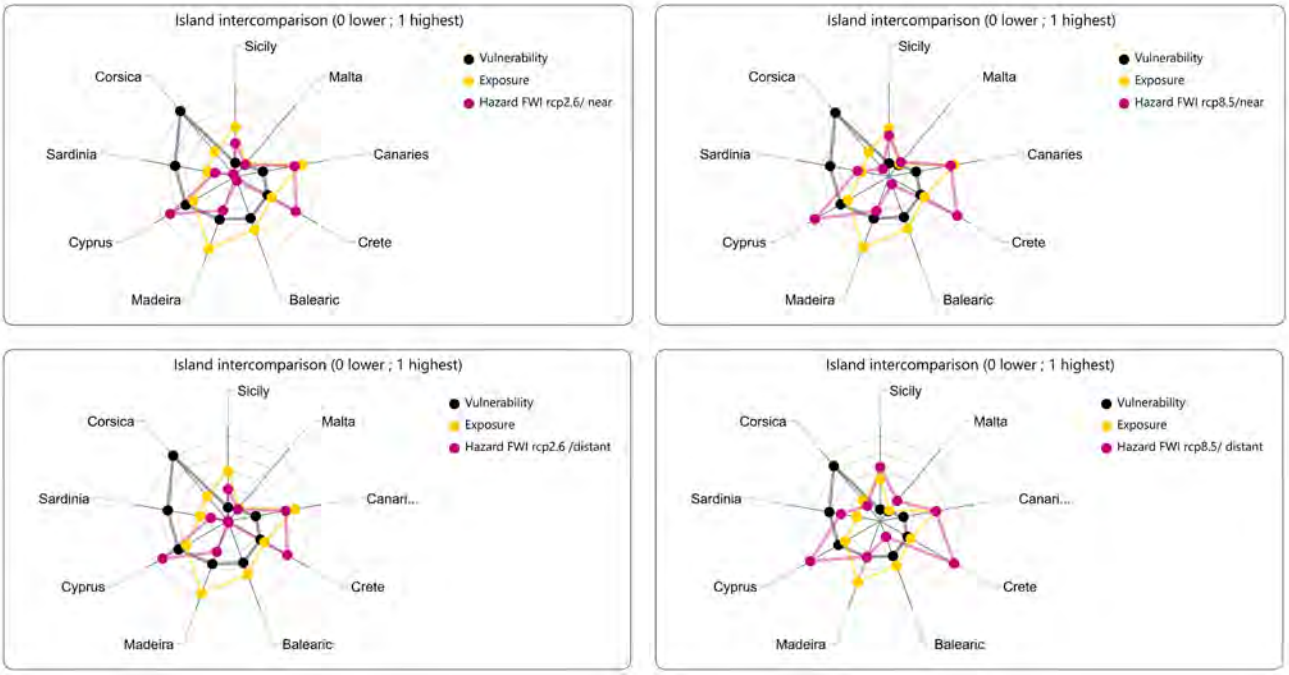


Figure 31. Score per component and per island in the near (2046-2065) and the distant future (2081-2100) under RCP2.6 (Ambitious Mitigation Policies) and RCP8.5 (Business as usual)

Appendix H: Methods for the Risk Assessment: Aquaculture

The expert team examined two possible methodologies for the implementation of the IC approach:

- The Analytic Hierarchy Process - AHP (Saaty, 1980).
- The Risk Assessment method proposed by Fritzsche *et al.* (2014), hereafter referred to as the GIZ method.

The AHP method provides a reference framework for decomposing a complex problem into more manageable sub-problems, thus concentrating on its constitutive elements, either quantifiable or not, and allowing the evaluation of their relative weights. It was, therefore, first adopted in order to familiarize with the structure and challenges of the Impact Chain approach. The method applied to the IC was "Increased fragility of the aquaculture activity due to an increase of extreme weather". Once a better understanding of the nature and relevance of risk components was gained through discussion among experts, the GIZ method was applied to the risk assessment analysis.

Evaluation of the AHP method

In general, the scores computed via the AHP only give some a priori comparative information about which risk components are relevant for the different islands and why, based on the information provided by the relative scores of criteria and sub-criteria. However, the weighing of the main risk components (i.e., the criteria vs goal comparison in the AHP terminology) set a big challenge for experts, which deserves further discussion, in particular as to the relative importance of hazard with respect to exposure and vulnerability. This is probably a consequence of the difficulty encountered to switch from the traditional risk assessment framework, where risk components are treated as independent, to the IC approach, where they jontly concur to the overall risk.

The results provide values for each island, which can be used to compare them. No absolute scores for islands can be given. However, information regarding the structure of the risk in each island can be extracted by comparing the criteria and sub-criteria analysed in the hierarchy tree. Not only the final relative scores are important, but also the scores obtained for each criteria and sub-criteria in the different islands. This could give relevant information to stakeholders by analysing which are the advantages and disadvantages of their aquaculture sector in comparison with other islands and learn from that.

Application of the GIZ method

In this context, the GIZ method was applied to analyse the data collected for some specific indicators reported in the IC, for the islands that showed interest in the risk assessment exercise for the aquculture sector and that were able to provide sufficient information. The corresponding ICs, therefore, needed to be simplified accordingly . When absolute criteria were available, the indicators were normalized, and the different risk components weighted, delivering risk scores for present and future conditions under different Representative Concentration Pathway (RCP) scenarios. Islands were then intercompared.

The method consists of seven steps:

- **Step 1:** Data collection by Island Focal Points.
- **Step 2:** Data review and selection of islands.
- **Step 3:** Review and selection of indicators.
- **Step 4:** Normalisation of indicator data for all islands.
- **Step 5:** Weighting of different risk components.
- **Step 6:** Calculations of risk for present conditions.
- **Step 7:** Calculations of risk for future conditions (different RCPs).

Some normalized values and all the weights were estimated by aquaculture experts based on subjective considerations, similar to those used in the AHP method. However, this time data availability was additionally considered, and weights lowered for the components that relied on less robust, outdated, or scarcer data. Components that were estimated from reliable datasets were given a higher weight. Conversely, wave hazards were normalized and classified based on absolute criteria, while for SST it was decided to present only the non-normalized hazard, due to the lack of a direct link relating warming to farm productivity.

Exposure and vulnerability sub-components had to be kept constant across scenarios and time horizons, due to insufficient information on future socio-economic development, and some had to be normalized via the max-min approach, which implies that they only allow the relative ranking of islands. However, in some cases, (i.e., the economic exposure component) this latter limitation might be acceptable as it is representative of the competitive advantages/disadvantages of each island in the context of the local market. Some discussion arose as to how to combine the two economic indicators available for exposure, that is the number of operators and annual production.

As a matter of fact, the number of producers was considered not to be relevant in itself, as it represents neither the absolute size of the sector nor its relevance for the island. The number of producers is, in fact, fairly homogeneous across the selected islands (from 7 to 12, with a mean value of 8.8), and fails to correctly rank the small but very active Malta with respect to, for instance, the much bigger, but apparently less developed in the sector, Sicily. The fact that weighted averaging the two indicators partly corrects this issue does not compensate for the apparent inconsistencies in the relative ranking. A new indicator, the average size of producers (computed as the ratio of production to the number of producers), was, therefore, proposed and examined, which proved to be more informative, as it effectively amplified differences between islands, at the same time retaining the absolute economic value of the sector (given by production), at least for the present situation. Indeed, the choice of the best indicators is affected by the necessity of guaranteeing their independence. Under current conditions, such independence is largely granted by the evident de-correlation of production and number of producers. Should a functional relation emerge in the future, a revision of the indicators is recommended. Normalization to the island size, or to the size of its economy, was considered to introduce exogenous factors in the sector evaluation, and it was consequently discarded in this context.

Economic indicators were, instead, excluded in the evaluation of adaptive capacity, perhaps limiting the conclusions of the risk assessment. It might be argued that the relative size of an industry could possibly give a measure of its capacity of overcoming temporary crises and investing in technological advancements that improve its survaivability under muted environmental conditions. Nevertheless, the relative relevance of Research and Development (R&D), profitability and long-term solvency in determining aquaculture firm survival is controversial (Cordón Lagares *et al.*, 2018), and the degree of innovation implemented by the enterprises currently operating in the islands unknown. In addition, simultaneously using the same indicator (average size of producers) for the computation of different risk components is anyway not advisable. The issue was, therefore, set aside in the present study.

IMPACT CHAIN: Decrease in production due to an increase in sea surface temperature

Hazard

Model projections are in good agreement with previous lower resolution ensemble estimates but offering greater detail along island shorelines. Uncertainty to be rigorously estimated from ensemble STD when new simulations of comparable resolution become available, but overall tendency regarded as robust.

Exposure and vulnerability indicators

The values in this analysis are not an estimate of the risk, but rather a ranking between islands, since a lot of the data was normalised based on a min-max or fraction of the maximum of the islands. A proper risk assessment would need additional data from farmers and a detailed model of farming results as a function of temperature. Malta has a much higher risk than the other islands due to the high exposure, Malta's farm produce on average 3.5 to 22 times more than the farms on other islands (see **Figures 32, 33** and **Table 3**).

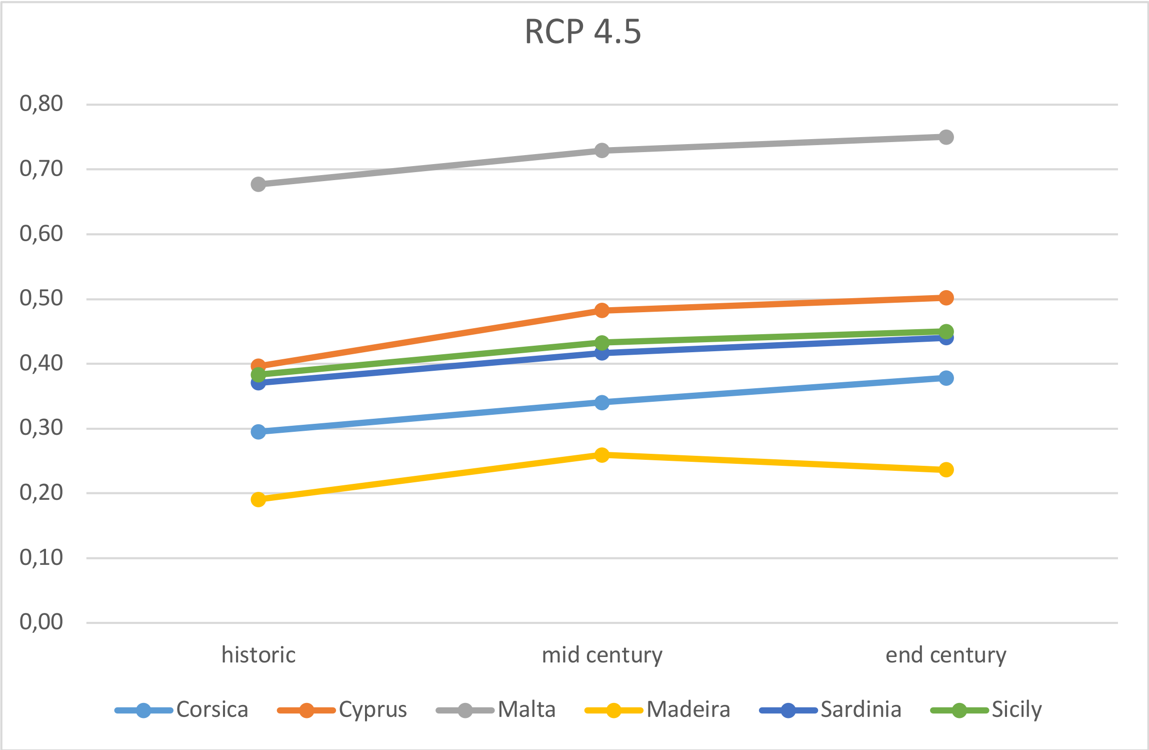


Figure 32. Risk results for impact chain sea surface temperature under RCP 4.5.

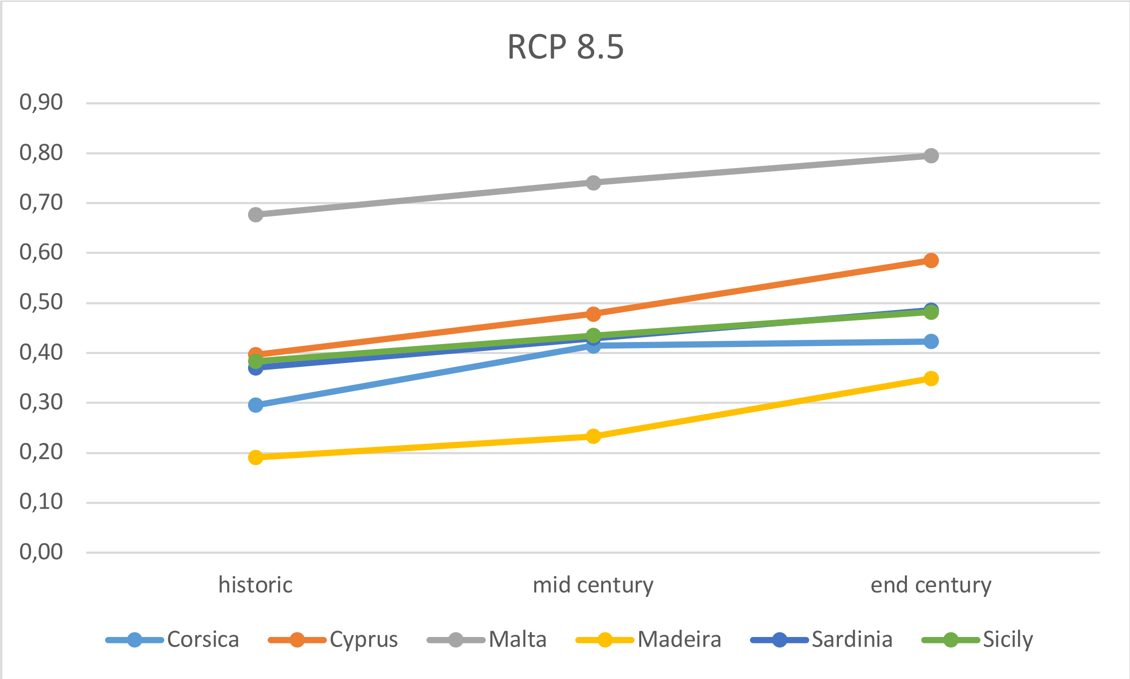


Figure 33. Risk results for impact chain sea surface temperature under RCP 8.5.

Table 3. Risk results for impact chain sea surface temperature.

Risk	Reference period	Mid century		End century	
	Hist.	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Corsica	0.30	0.34	0.41	0.38	0.42
Cyprus	0.40	0.48	0.48	0.50	0.59
Malta	0.68	0.73	0.74	0.75	0.80
Madeira	0.19	0.26	0.23	0.24	0.35
Sardinia	0.37	0.42	0.43	0.44	0.49
Sicily	0.38	0.43	0.43	0.45	0.48

IMPACT CHAIN: Increased fragility of the aquaculture activity due to increase of extreme weather

Mediterranean islands

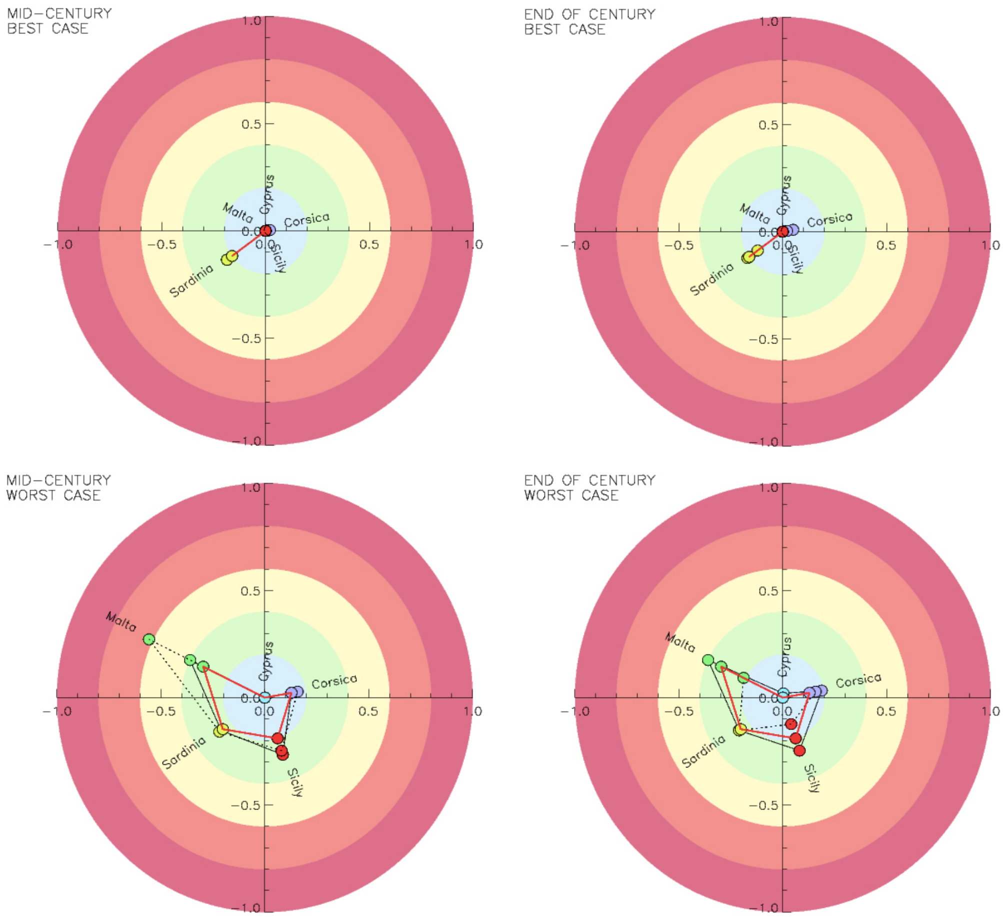
Hazards

Statistics of extreme events can significantly differ across the four model realizations.

The hazard data for return time was derived from 3 different models: CMCC, CNRM and GUF. Since the data varies highly between models a best- and worst-case scenario was executed, where in the best-case scenario the lowest value (showing the lowest risk) between the models was used and in the worst-case scenario the highest value was applied. Distance between the best and the worst projection give an estimate of uncertainty.

Model projections for Average Significant Wave Height are in good agreement as to both pattern and values. Hazard was evaluated from ensemble mean, uncertainty from ensemble STD (not exceeding 15% - highest disagreement for highest values) (see **Figure 34**).

"Worst" and "best" cases respectively refer to the least and most favorable projection in the set of models. For example,



Return time

Figure 34. Results for return time in best- and worst-case scenarios for Mediterranean islands for reference period (red line), RCP 4.5 (dotted line) and RCP 8.5 (black line).

regarding return time, you will find that there is at least one model predicting no hazard for all islands except Sardinia with no significant variations across scenarios. In fact, all circles cluster and overlap at the centre, while those that represent Sardinia all lie very close to the limit between the two lower hazard classes.

On the other hand, at least one other model predicts appreciable yet low hazard for Corsica, Sicily and Sardinia, and hazard going from moderate (reference period, red) to medium (RCP8.5, solid black), to high (RCP4.5, dotted black) for Malta, while for Cyprus the hazard is irrelevant even for the most negative projection.

This means that

a. The result for Sardinia and Cyprus is stable across models.

b. Models slightly disagree for Sicily and Corsica, but generally predict low hazard.

c. The projection for Malta is affected by greater uncertainty for all scenarios.

This is due to the fact that Malta is located in the Sicily Channel, where the dynamics exhibit significant gradients in the direction perpendicular to the channel axis, which are differently represented by several models.

The worst and best cases do not necessarily come from the same model for all islands, that is, one model can predict the lowest hazard for Sicily and another one for Sardinia, and each of these projections is represented in the plot for the corresponding island (see **Table 4, Figures 35, 36** and **Table 5, Figures 37, 38**).

Table 4. Risk results for best-case scenario for impact chain "Extreme Weather Events".

Risk	Reference period	Mid century		End century	
	Hist.	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Corsica	0.19	0.19	0.19	0.20	0.21
Cyprus	0.23	0.23	0.23	0.23	0.22
Malta	0.26	0.26	0.26	0.26	0.26
Sardinia	0.30	0.32	0.32	0.28	0.31
Sicily	0.20	0.20	0.20	0.20	0.20

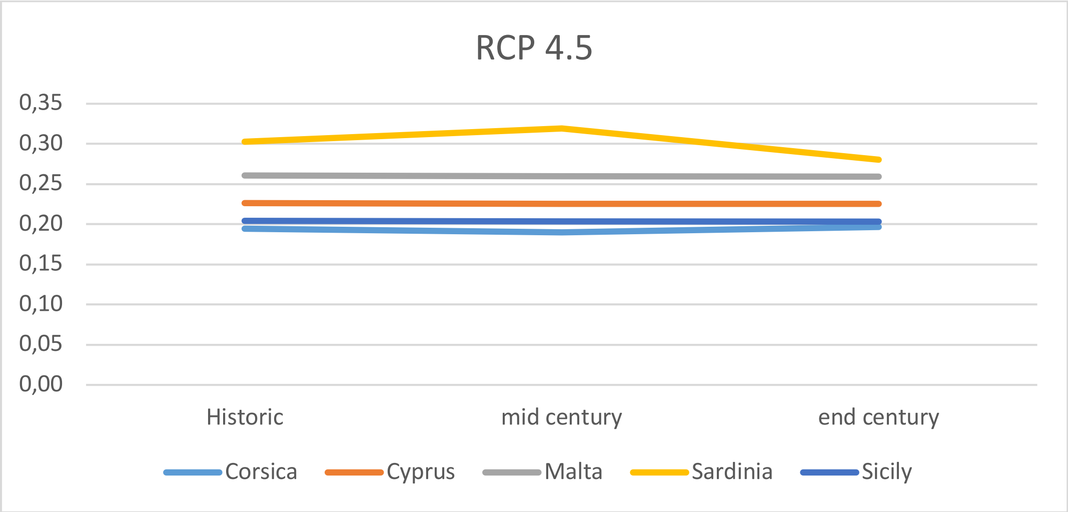


Figure 35. Risk results for best-case scenario for impact chain extreme weather events under RCP 4.5.

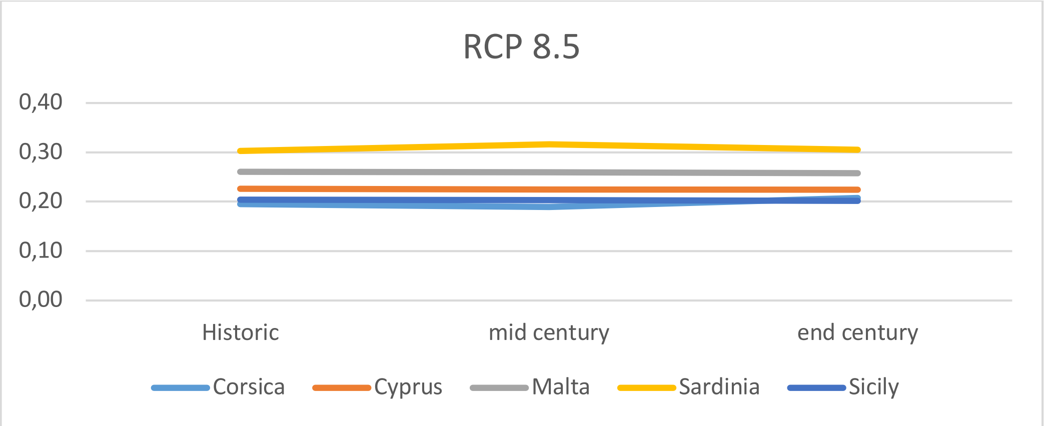


Figure 36. Risk results for best-case scenario for impact chain extreme weather events under RCP 8.5.

Table 5. Risk results for worst-case scenario for impact chain "Extreme Weather Events".

Risk	Reference period	Mid century		End century	
	Hist.	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
Corsica	0.25	0.25	0.26	0.28	0.26
Cyprus	0.23	0.23	0.23	0.23	0.22
Malta	0.42	0.45	0.56	0.45	0.36
Sardinia	0.33	0.33	0.34	0.33	0.33
Sicily	0.30	0.34	0.33	0.33	0.26

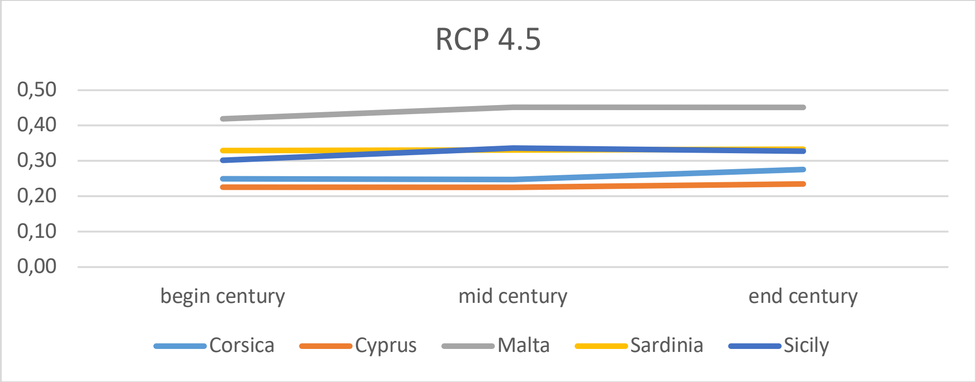


Figure 37. Risk results for worst-case scenario for impact chain extreme weather events under RCP 4.5.

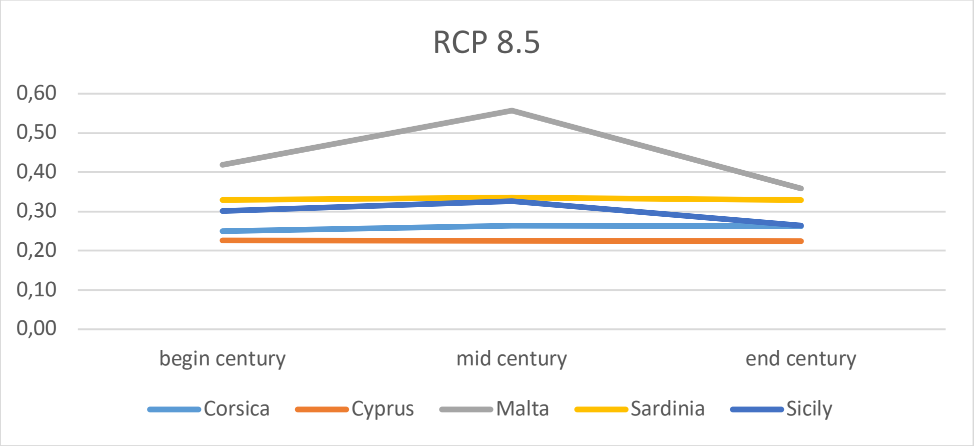


Figure 38. Risk results for worst-case scenario for impact chain extreme weather events under RCP 8.

Bigger islands were separated in areas, since conditions can vary greatly in different parts of the island (see **Table 6**).

For all islands and all RCPs, it can be concluded that there is no significant change in risk, even in the worst-case scenario, between the reference period, middle and end of the century. Malta, southern Sicily and western Sardinia are found to be the most vulnerable with risk exceeding 0.45 due to a higher hazard risk. Malta also has the highest exposure of all islands. Malta has an increased in the risk mid-century in the worst case scenario due to an increase in hazard.

Table 6. Risk results for impact chain "Extreme Weather Events" for the Mediterranean islands with large islands analysed on a local level using the worst-case scenario.

Worst case	Historic	RCP 4.5		RCP 8.5	
		Mid century	End century	Mid century	End century
Malta	0.37	0.45	0.45	0.56	0.36
Sicily North	0.34	0.39	0.39	0.36	0.30
Sicily East	0.17	0.20	0.20	0.20	0.20
Sicily South	0.41	0.42	0.40	0.42	0.30
Corsica West	0.37	0.32	0.37	0.34	0.34
Corsica East	0.18	0.18	0.18	0.18	0.19
Sardinia West	0.40	0.46	0.47	0.47	0.44
Sardinia East	0.39	0.20	0.20	0.20	0.18
Cyprus	0.23	0.23	0.23	0.23	0.22
	0.00 – 0.20 Very low	0.20 – 0.40 Low	0.40 – 0.60 Medium	0.60 – 0.80 High	0.80 – 1.00 Very high

Atlantic islands

For the Atlantic islands, 2 models are available (Hadley Centre and ACCESS) for data on return time. The results of these models are highly variable. For the Azores, even the change of the risk is different, where the Hadley riley model shows a decrease in risk while ACCESS shows a significant increase in risk. Therefore, no conclusion can be made. For Madeira, the risk in the future will be non-existent. Not considering probability, it could be concluded that climate change has no or a positive effect on the occurrence on extreme events in Madeira. However, since this data is not accurate, more work needs to be done (see **Table 7**).

Table 7. Risk results for impact chain "Extreme Weather Events" for the Atlantic Islands.

Risk	Hadley centre			ACCESS		
	Historic	RCP 8.5 Mid century	RCP 8.5 End-century	Historic	RCP 8.5 Mid century	RCP 8.5 End-century
Azores	0.83	0.76	0.79	0.15	0.41	0.67
Madeira	0.20	0	0.01	0	0	0

Source: SOCLIMPACT project deliverable 4.5

Appendix I: Methods and instruments for the Risk Assessment: Energy

Hazard indicator computation and normalization

Cooling Degree Days (CDD)

Cooling Degree Days (CDD) are used to give an indication of the effect of outside air temperature on building energy consumption during a specified period of time. The Cooling Degree Days (CDD) index gives the number of degrees and number of days that the outside air temperature at a specific location is higher than a specified base temperature.

The calculation of CDD relies on the base temperature, defined as the highest daily mean air temperature not leading to indoor cooling. The value of the base temperature depends in principle on several factors associated with the building and the surrounding environment. Different base temperatures have been tested in order to select the value that can adequately represent all the islands of the current analysis. The base temperature here has been set as T_{base} = 21 °C.

Then, the index is calculated as follows:

If $T_m \geq 24$ °C Then [CDD = $\sum_i T^i_m - 21$ °C)] Else [CDD = 0]
where T^i_m is the mean air temperature of day i.

The index has been calculated on a monthly basis for the period 1981-2100 for all islands, climate models, and scenarios. The calculation was performed for each one of the selected pairs of global climate models/regional climate models. The ensemble mean and uncertainty (described by the pooled standard deviation) have been obtained for 20-year time-averages, for the reference period (1986-2005), as well as the two future periods of interest (2046-2065 and 2081-2100) for the two selected RCPs for EURO-CORDEX and MENA-CORDEX simulations. Then, the grid cells that represent a land fraction: l.f. > 15% for the islands were retained for the analysis.

For the indicator weight calculation in the islands, where the impact chain has been operationalized, observed values of CDD (EUROSTAT) have been used. For Gran Canaria, the NUTS3 data for the whole archipelago have been taken as for the island itself only 2 years were available.

With respect to the normalization of the indicator, we have used a fixed lower threshold and a relative maximum as upper threshold. The minimum CDD value has been taken as 0, while the maximum CDD value has been taken as the maximum over all islands, emissions scenarios and time periods (1183.49 °C · days/year, corresponding to Cyprus for RCP8.5 scenario, end of century period).

Standardised Precipitation-Evapotranspiration Index (SPEI)

SPEI is a drought index that takes into account not only the effect of precipitation variations, but also the effect of temperature variations on evapotranspiration. The calculation is based on the monthly difference between precipitation and potential evapotranspiration, which represents the monthly water surplus or deficit. The monthly differences can be aggregated at different time-scales, depending on the type of drought to be monitored. In our case, a 12-month aggregation has been used. More details on SPEI and its computation can be found in Beguería *et al.*

Temperature and precipitation data for SPEI calculation have been taken from the selected regional climate model simulations. Regarding the indicator weight calculation for the islands, for which the impact chain has been operationalized, ECA&D (European Climate Assessment & Dataset) data have been used for Malta and Cyprus, while for Gran Canaria local data have been applied (Plan Hidrológico de Gran Canaria, 2019).

The normalization of the indicator has taken into account the fact that, by definition, present conditions correspond to reference conditions (SPEI = 0), and that all future changes are towards negative SPEI values, that is towards drier conditions. Therefore, the best score value (0) has been assigned to SPEI = 0, while the worst score value (1) has been assigned to the largest negative value found for all islands, emissions scenarios and time periods (SPEI = -2.5, obtained for several islands under RCP8.5 emissions scenario by the end of century).

Wind energy productivity

This indicator (W_{prod}) will show the present wind energy potential and its projected future evolution. Here, productivity (kWh/kW) is defined as the energy produced in a period of time divided by the power installed, which is considered as unitary.

We first derive the wind speed at the surface (10 m, W_{10}) from 6-hourly U10 and V10 wind components of the simulations considered. Then, we calculate the wind speed W_H at the turbine hub height (H = 100 m for wind energy over land; H = 150 m over the sea). From Tobin *et al.* (2015):

$$W_H = W_{10} \cdot \left(\frac{H}{10}\right)^{\alpha}$$

$$\alpha = \frac{1}{7}$$

After calculating W_H at the turbine hub height, we calculate wind potential (W_{pot}) as in Jerez *et al.* (2015). However, in order to do that, W_H must be regarded as the average of the wind speed at 6-hours intervals (Wav):

$$Wav\ (t_{\frac{2i+1}{2}}) = \frac{[W_H\,(t_i) +\ W_H\,(t_{i+1})]}{2}$$

$$W_{pot} = \begin{cases} 0 & \text{if} \quad V < V_I \\ \frac{V^3 - V_I^3}{V_R^3 - V_I^3} & \text{if} \quad V_I \le V < V_R \\ 1 & \text{if} \quad V_R \le V < V_O \\ 0 & \text{if} \quad V \ge V_O \end{cases}$$

where V_I = 3 m/s (cut-in wind velocity); V_R = 12 m/s (rated velocity); V_O = 25 m/s (cut-out velocity) and V = W_{av}.

Finally, wind productivity (W_{prod}) is calculated from the wind potential produced by the 6-hr averaged wind multiplied by the number of hours (6 hours).

The indicator is calculated separately for land and sea. Offshore wind energy is the most developed ocean energy, and it is likely to be an important future energy source for the analysed islands. Its characteristics are typically very different to onshore wind energy, due to the large differences in surface friction. The energy productivity values are averaged respectively over the island land points and over the sea points in a domain that reaches a maximum distance of one degree latitude and longitude respectively to the maximum and minimum longitude/latitude land points of the islands.

The normalization is performed using absolute thresholds that represent high or low global values of productivity. These thresholds have been obtained from a global renewable power report (IRENA, 2019). In this report, 5^{th} and 95^{th} percentiles of renewable energy capacity factors (CFs) are given for the period 2010-2018. The minimum and maximum thresholds are estimated as rounded values deduced respectively from the 5^{th} and 95^{th} percentiles shown in the report. The conversion from productivity values to CFs in percentage terms is done as follows:

CF = (Productivity/8760)*100

where 8760 is the annual number of hours. The maximum annual productivity would be 8760 kWh/kW, corresponding to a 100% capacity factor.

The obtained CF thresholds for onshore wind energy are 20% (corresponding to a normalized score of 1) and 45% (normalized score of 0), while for offshore energy they are 30% and 50%.

Photovoltaic productivity

This indicator will show the present solar photovoltaic (PV) potential and its projected future evolution. Productivity (kWh/kW) is defined as the energy produced in a period of time divided by the power capacity installed.

In order to obtain photovoltaic productivity, daily surface solar radiation (SSR) and ambient temperature from the climate simulations are used as input variables for a parametric PV model.

The PV modelling process can be summarised in two steps: first, incident solar radiation that reaches solar cells inside the panels is obtained through the decomposition of global solar irradiation and the transposition to the plane-of-array. After that, the electrical performance of the photovoltaic system is modelled in order to obtain daily PV productivity (PV_{prod}). To obtain annual or monthly statistics, the respective sum of daily productivity is computed in each case (Gutiérrez *et al.*, 2020).

The normalization is performed using absolute thresholds that represent high or low global values of productivity, taken from the same report as for wind energy. In this case, the maximum threshold is adapted taking into account that the calculations performed here assume fixed panels, while IRENA global report does not differentiate between fixed and sun-tracking panels. The use of tracking increases the capacity factor by 5 percentage points for the best resource locations (Bolinger *et al.*, 2019). Therefore, we estimate an upper CF treshold (normalized score of 0) of 20% for fixed panels, from the 25% value deduced from IRENA global report. The lower CF threshold obtained from the latter report is 10% (normalized score of 1).

Renewable energy productivity droughts

Photovoltaic and wind energy productivity droughts are calculated as an indicator of productivity steadiness in the analysed European islands. Renewable energy droughts can be regarded as low-productivity periods during which the daily productivity takes values below a low-productivity threshold. To systematically identify energy droughts, a Deficiency Index (DI) is computed following Raynaud *et al.* (2018). This is defined as follows:

$$DI(i,j) = 1 \text{ if } P(i,j) \le P_0(i,j)$$

$$DI(i,j) = 0 \text{ if } P(i,j) > P_0(i,j)$$

where P is the daily productivity (kWh/kW) computed as explained in sections 2.1 and 2.2, and P_0 the corresponding low-productivity threshold. Productivity thresholds are calculated as a percentage of the mean daily productivity estimated for the control time period, which goes from 1986 to 2005. These thresholds are also used to determine energy productivity droughts in the scenarios. Two different thresholds are calculated to determine moderate (50% of mean daily productivity) and severe (20% of mean daily productivity) energy productivity droughts, respectively. For clarity, only the moderate energy productivity droughts are presented in the tables in section 3. In order to illustrate the level of complementarity of solar and wind energy, combined photovoltaic and wind productivity droughts are also calculated, assuming a 50/50 distribution of solar and wind power capacity. Energy productivity droughts have been calculated as spatial averages over land points.

For the normalization of these energy drought indicators, we have used a combination of an absolute threshold (a value of 0% of drought days) corresponding to a score of 0 and a relative maximum upper limit, taken among all the islands and renewable energy technologies (55% of days with moderate droughts, obtained for wind energy in Corsica) corresponding to a score of 1. The same normalization limits are applied for wind, PV and combined productivity droughts.

Renewable energy productivity changes

The available literature on the impact of climate change on wind and PV energies shows that the future projected changes frequently do not exceed a level of 10% relative to present values over the studied area (Solaun and Cerdá, 2019). Such a change would produce rather limited changes in the normalized scores if we maintained the same approach for future values. Though changes of about 10% do not impact strongly on a normalized score, they are a significant impact on the productivity and profitability of the energy plants. On the other hand, in the case of renewable energies, both increases and decreases in future productivity are projected, and this should be taken into account in the normalized values.

Also, the relatively large uncertainty in certain variables like wind from climate models makes relative changes more reliable than absolute values (Solaun and Cerdá, 2019). Therefore, we have used change indicators instead of the future values of the same indicators used for present climate conditions, in such a way that positive changes can be differentiated from negative changes. The normalized values for the projected changes are calculated through a weighted combination of a term comparing the change in the particular island to an overall fixed change threshold of 10% and a term comparing the change in a particular island to the changes in other islands.

These normalized values in the different islands, time periods and scenarios of study are expressed through the Nc index. A value of Nc equal to 0.5 indicates no future change. When Nc > 0.5, projected changes are unfavorable, being Nc = 1 the worst possible scenario. This entails that productivity (droughts) decreases (increase). On the contrary, values of Nc < 0.5 indicate a favorable future change, being Nc = 0 the best possible scenario. The Nc index is defined as follows:

$$Nc = 0.25 \cdot A + 0.75 \cdot B$$

The terms A and B are individually normalized as explained below:

A: This term serves to estimate the projected change in a region with respect to the rest of the islands.

To calculate it we first compute (for each indicator, time period and scenario), the absolute maximum ensemble mean increase (Δmax) and the absolute maximum ensemble mean decrease (Δmin) of all the islands. In the case of productivity, Δmax and Δmin are provided in kWh/kWp. In the case of energy productivity droughts, Δmax and Δmin are given in absolute change (%).

Then, we compare the ensemble mean change for a given island, time period and scenario (Δmean) to the maximum change encountered for the corresponding case taking into account all islands. For the productivity case, Δmean is given in kWh/kWp. In energy productivity droughts, Δmean is provided as absolute change (%). Specifically, if Δmean > 0, Δmean is compared to Δmax. Alternatively, if Δmean < 0, Δmean is compared to Δmin. In each case, the value of A is estimated with a linear regression as follows:

- Wind and photovoltaic productivity:

  When productivity changes are positive (Δmean > 0), the normalized A would go from 0 to 0.5, whereas if they are negative (Δmean < 0), the normalized value of A would go from 0.5 to 1. In order to obtain the value of A within each interval the productivity changes correspond to, a linear regression is applied as follows:

  Positive mean changes:

$$A = \frac{-0.5 \cdot \Delta mean}{\Delta max} + 0.5$$

  Negative mean changes:

$$A = \frac{0.5 \cdot \Delta mean}{\Delta min} + 0.5$$

- *Energy productivity droughts:*

  If productivity changes are positive (Δmean > 0), the normalized A ranges from 0.5 to 1, whereas negative changes (Δmean < 0) correspond to a normalized value of A that varies between 0 and 0.5. In order to obtain the value of A, a linear regression is applied as specified below:

  Positive mean changes:

$$A = \frac{0.5 \cdot \Delta mean}{\Delta max} + 0.5$$

  Negative mean changes:

$$A = \frac{-0.5 \cdot \Delta mean}{\Delta min} + 0.5$$

B: This term allows us to evaluate the magnitude of the change projected for each island, time period and scenario with respect to a fixed change threshold.

To do so, we express the relative change of the indicators with respect to the control time period (1986-2005) in percentage ($\Delta mean_{per}$) and compare it to a threshold of ± 10%.

In each case, the value of B is calculated with a linear regression as specified below:

- Wind and photovoltaic productivity:

  When productivity changes are positive, and bigger than 10% ($\Delta mean_{per} \geq 10\%$), the normalized B is set to 0, whereas if they are negative, and smaller than –10% ($\Delta mean_{per} \leq -10\%$), the normalized value of B is set to 1. In order to obtain the normalized value of B between –10% and 10% a linear regression is applied as follows:

$$B = \frac{1}{20} \cdot \left(10 - \Delta mean_{per}\right)$$

- Energy productivity droughts:

  Relative changes in the frequency of energy productivity droughts which are positive and greater than 10% ($\Delta mean_{per} \geq 10\%$) correspond to a normalized B of 1. If relative changes in the occurrence of energy productivity droughts are negative and smaller than –10% ($\Delta mean_{per} \leq -10\%$), the normalized value of B is set to 0. The normalized value of B is obtained with a linear regression as follows:

$$B = \frac{1}{20} \cdot \left(10 + \Delta mean_{per}\right)$$

Risk indicator computation I: normalization of indicators

For the operationalization of the full impact chains regarding cooling and desalination energy demand, the normalization of exposure and vulnerability indicators has been performed as follows (the normalization of climate hazard indicators CDD and SPEI has been explained above):

Exposure

Residents Population

For this exposure indicator, we have selected population density, as this quantity allows for a direct comparison among islands independently of their land area. For the normalization, we have used a fixed lower threshold (0 persons/km^2) corresponding to a score of 0, while for the maximum threshold we have used the maximum population density in the EU, found in Malta (1372.76 persons/km^2, in average over 2007-2018), corresponding to a score of 1. EUROSTAT values have been used for Cyprus and Malta, while the data for Canary Islands have been obtained from ISTAC (Canary Statistical Institute).

Number of tourists

In this case, we have assumed that the impact of tourists on electricity demand will depend more on a tourism intensity indicator than on the absolute number of tourists. We have selected the ratio Tourist Number/Population, used in Manera and Valle (2018). In this paper, a maximum value of 4.42 tourists/resident is found over the EU in 2014. This value is used as a maximum threshold for normalization (score 1), while a fixed absolute value of 0 tourists/resident is used as the minimum threshold (score 0). The annual numbers of tourists are taken from local statistical sources for Cyprus and Gran Canaria, while for Malta they are taken from EUROSTAT.

Tourism seasonality

We have developed an indicator summarising the main characteristics of tourism variability over the year. Tourism seasonality will be high if the maximum monthly number of tourists is much higher than the average monthly number of tourists. There will be no seasonality if the monthly maximum number of tourists is equal to the monthly average number of tourists (this corresponds to a constant monthly number of tourists). For the normalization, we have used the following equation:

Tourism seasonality =
(Monthly maximum/Monthly average) – 1

which will be equal to 0 if there is no seasonality. If the monthly maximum is double the average, the score will reach a value of 1. Values above this are capped to 1. Local data sources are used in this case for the 3 islands.

Cooling penetration rate

The cooling penetration rate is the percentage of households using air conditioning. Though it could be variable, and particularly increasing in a warming climate, we have not found data sources with time-series for this variable. Its value is rather high in Cyprus (80.8% in 2009, 80.15% in 2019) and Malta (70% in 2009), and low in Canary Islands (12.8% in 2018; La Vanguardia, 2018), in good correspondence with summer temperatures. Due to the absence of time-varying data for this indicator, it is not possible to apply in this case the same correlation-based method for weighting as for other indicators, and therefore, we have not used it in the operationalization of the impact chains.

Percentage of desalinated water with respect to total water

For this indicator, time-series are available from local sources. For Gran Canaria, the percentage has increased from 20% in 1990 to more than 50% over the last few years. For Cyprus, data from 2010 to 2017 show variations between 4% in 2012 and 31% in 2017, while for Malta this indicator varies between 55% and 61% in the period 2004-2018. The normalization in this case is straightforward, based on fixed thresholds: 0% of desalinated water corresponds to a score of 0, while 100% of desalinated water is associated to a score of 1.

Vulnerability (Sensitivity)

Energy intensity

This indicator is an efficiency measure, calculated here as electricity consumption divided by GDP (2000-2018 average). Data have been taken from EUROSTAT for Malta and Cyprus, while for Gran Canaria they have been obtained from ISTAC. A minimum/maximum approach has been used for normalizing this indicator. The island values have been compared to EU values, taking two extreme percentiles (10 and 90) among EU countries. Percentiles have been used instead of direct minimum/maximum values in order to remove the effect of outliers. In this case, a score of 0 has been associated to the 10th percentile of energy intensity, while a score of 1 has been assigned to the 90th percentile of energy intensity.

Per capita energy demand

Data for per capita electricity demand have been obtained from the same sources as energy intensity, and the normalization has been done using the same approach (minimum/maximum with 10th and 90th percentile among EU countries). The calculation has been done dividing the electricity consumption by the population, and the score has been calculated using the 2000-2018 average value of per capita electricity demand.

Vulnerability (Adaptive Capacity)

Purchasing power for increased consumption (Per capita GDP)

This indicator is a measure of the capacity to fulfill consumption needs. It has been calculated dividing the GDP by the population, using the same sources as for the above sensitivity indicators. A 2000-2018 average value has been used for calculating the score. A minimum/maximum approach has been applied for the normalization, using again 10th and 90th percentiles among EU countries. In this case, a high per capita GDP indicates a higher capacity for covering consumption needs, so the best score (0) has been assigned to the 90th percentile of per capita GDP, while the worst score (1) has been assigned to the 10th percentile of per capita GDP.

Demand side management

This indicator is a qualitative measure of the existence or absence of demand side management measures for reducing cooling or desalination consumption. An example of management measure is the reduction of water leakages in the water distribution network. As a qualitative (binary) indicator, only "yes" or "no" values are assigned, which are considered in the discussion of the risk, but not in the calculation of the risk score. Local data sources have been used in this case.

Risk indicator computation II: weighted aggregation of components

The weighting of the different risk components has been done using an objective approach. The observed time-series of cooling and desalination demand have been correlated to the observed time-series of every indicator. Higher correlation values for an indicator have been associated to a higher weight. The detailed weight calculation for the risk components (hazard, exposure and vulnerability) has been performed applying the following method, developed by ITC (Gran Canaria).

The mathematical procedure developed proposes the definition of weights per group of variables (hazard, vulnerability and exposure) that allow identifying the relationship between each of the explanatory variables (the indicators defined in the previous section) and the response analyzed (in this case, energy demand due to desalination or energy demand due to cooling). The procedure consists of several steps:

- Step 1- Linear correlation

  In this step, the linear correlation coefficient of n pairs (x, y) is calculated as follows:

$$r_{xy} = \frac{SS_{xy}}{\sqrt{SS_{xx} \cdot SS_{yy}}}$$

  where:

$$S_{xx} = \sum x^2 - \frac{1}{n}\left(\sum x\right)^2$$
$$S_{xy} = \sum xy - \frac{1}{n}\left(\sum x\right)\left(\sum y\right)$$
$$S_{yy} = \sum y^2 - \frac{1}{n}\left(\sum y\right)^2$$

  - x = every explanatory variable (population density, GDP per capita, etc.).
  - y = objective variable (energy demand due to desalination).
  - n = years of historic data (considering the last year as the last for which there are values for the objective variable).
  - = Linear correlation between x (explanatory variables) and y (risk).

In the case of the desalination demand IC, the detailed calculations are as follows:

- Exposure:
  - = Linear correlation coefficient between total annual energy demand for desalination and resident population density.
  - = Linear correlation coefficient between total annual energy demand for desalination and the yearly tourist number indicator.
  - = Linear correlation coefficient between total annual energy demand for desalination and the tourism seasonality indicator (based on the yearly maximum number of tourists).
  - = Linear correlation coefficient between total annual energy demand for desalination and the percentage of desalinated water with respect to total water demand.
- Vulnerability:
  - = Linear correlation coefficient between total annual energy demand for desalination and the yearly gross domestic product per capita.
  - = Linear correlation coefficient between total annual energy demand for desalination and per capita energy demand.
  - = Linear correlation coefficient between total annual energy demand for desalination and energy intensity.
- Hazard:
  - = Linear correlation coefficient between total annual energy demand for desalination and standardized precipitation evapotranspiration index.
  - In the case of the cooling demand IC, the calculations are the same except that the correlation between the desalination demand and the percentage of desalinated water is not used, and for the hazard correlation, cooling degree days are used instead of the standardized precipitation evapotranspiration index for calculating.
- Step 2- Weight

  In this step, the weight per group of variables (exposure, vulnerability and hazard) is established.

$$w_{Exposure} = \frac{W_{exp}}{W_{exp} + W_{vul} + w_{haz}}$$

$$w_{Vulnerabilty} = \frac{W_{vul}}{W_{exp} + W_{vul} + w_{haz}}$$

$$w_{Hazard} = \frac{W_{haz}}{W_{exp} + W_{vul} + w_{haz}}$$

where:

$$W_{exp} = \frac{\sum_{i=1}^{n_{exp}} |r_{Dexp}|}{n_{exp}}$$

$$W_{vul} = \frac{\sum_{i=1}^{n_{vul}} |r_{Dvul}|}{n_{vul}}$$

$$W_{haz} = \frac{\sum_{i=1}^{n_{haz}} |r_{Dhaz}|}{n_{haz}}$$

- = weight of the exposure group
- *n_exp, n_vul, n_haz* = number of variables for each type (exposure, vulnerability and hazard)
- = absolute value of the linear correlation coefficient between every exposure variable and the energy demand due to desalination.

In the case of the desalination demand IC:

$$W_{exp} = \frac{|r_{DR}| + |r_{DT}| + |r_{DMAXT}| + |r_{DDWD}|}{4}$$

$$W_{vul} = \frac{|r_{DGDP}| + |r_{DC}| + |r_{DEI}|}{3}$$

$$w_{haz} = |r_{DSPEI}|$$

In the case of the cooling demand, IC is not used for the exposure weight, and is used instead for the hazard weight.

The weights obtained for every IC and island are the following (see **Tables 8 and 9**):

Table 8. Weight scores for desalination impact chain.

Desalination IC	W_{haz}	W_{exp}	W_{vul}
Gran Canaria	0.31	0.35	0.34
Malta	0.20	0.38	0.42
Cyprus	0.04	0.52	0.44

Table 9. Weight scores for cooling impact chain.

Cooling IC	W_{haz}	W_{exp}	W_{vul}
Gran Canaria	0.31	0.27	0.42
Malta	0.16	0.48	0.36
Cyprus	0.16	0.48	0.36

Appendix J: Methods for the Risk Assessment: Risk of Isolation due to Transport Disruption

The hazard risk component indicators considered were: extreme waves (SWHX98), extreme wind (WiX98) and mean sea level rise (MSLAVE). The exposure indicators are: number of passengers (NPax), islands' total population (NTotP), value of transported goods expressed in freight (VGTStot) and number of ports per island or archipelago (NPo), while the sensitivity indicators include: the number of isolation days (NIID) and renovated infrastructure (NAgePo). Finally, for the component of adaptive capacity, the proposed indicators are: percentage of renewables (PEnRR), number of courses/trainings (NTrCoRM), early warning systems (NOcSta) and harbour alternatives (NApt). Unfortunately, due to the lack of reliable and consistent data, we had to exclude the number of isolation days and number of courses/trainings indicators.

For assessing future risk, we considered projections or estimations for the indicators when these were available. This was mainly the case for the components of hazard (mean sea level rise, extreme waves and wind), exposure (population, number of passengers, value of goods), and the contribution of renewables. Two Representative Concentration Pathways (RCPs) were considered for meteorological hazards. One "high-emission" or "business-as-usual" pathway (RCP8.5) and a more optimistic one (RCP2.6) that is closer to the main targets of the Paris accord to keep global warming to lower levels than 2 °C since pre-industrial times.

Besides the historical reference period, we consider two 20-year future periods of analysis. One over the middle of the 21st century (2046-2065) and one covering the end of the 21st century (2081-2100). The normalization of indicators was performed across the different islands in order to facilitate an inter-island comparison and prioritize the islands of higher risk (see **Figure 39**).

Regarding the weighting of the different risk components, we have tested several weights; however, according to expert judgement and discussion with specialists on the maritime sector, we have found more appropriate to assign equal weights to all main components of risk (i.e., 0.33 for hazard, 0.33 for exposure and 0.33 for vulnerability). For the sub-components of exposure, we have assigned a weight of 0.33 for nature of exposure and a weight of 0.66 for level of exposure since the latter one is believed to be of greatest importance. Similarly, for the vulnerability sub-components, we have assigned a weight of 0.25 for the factors of sensitivity and a weight of 0.75 for the factors of adaptive capacity.

The weighting and categorization of risk is a subjective decision, nevertheless we consider our selection to be quite conservative and, therefore, we believe that a slightly different choice would not significantly affect the main conclusions drawn. For the recent past/present conditions, the operationalization of the maritime transport impact chain indicates low risk for all investigated islands. In general, the maritime transport sector of the larger islands (e.g., Corsica, Cyprus and Crete) is found to be more resilient to the impacts of climate change. Up to a point, this is related to the large number of harbour alternatives in comparison with smaller islands.

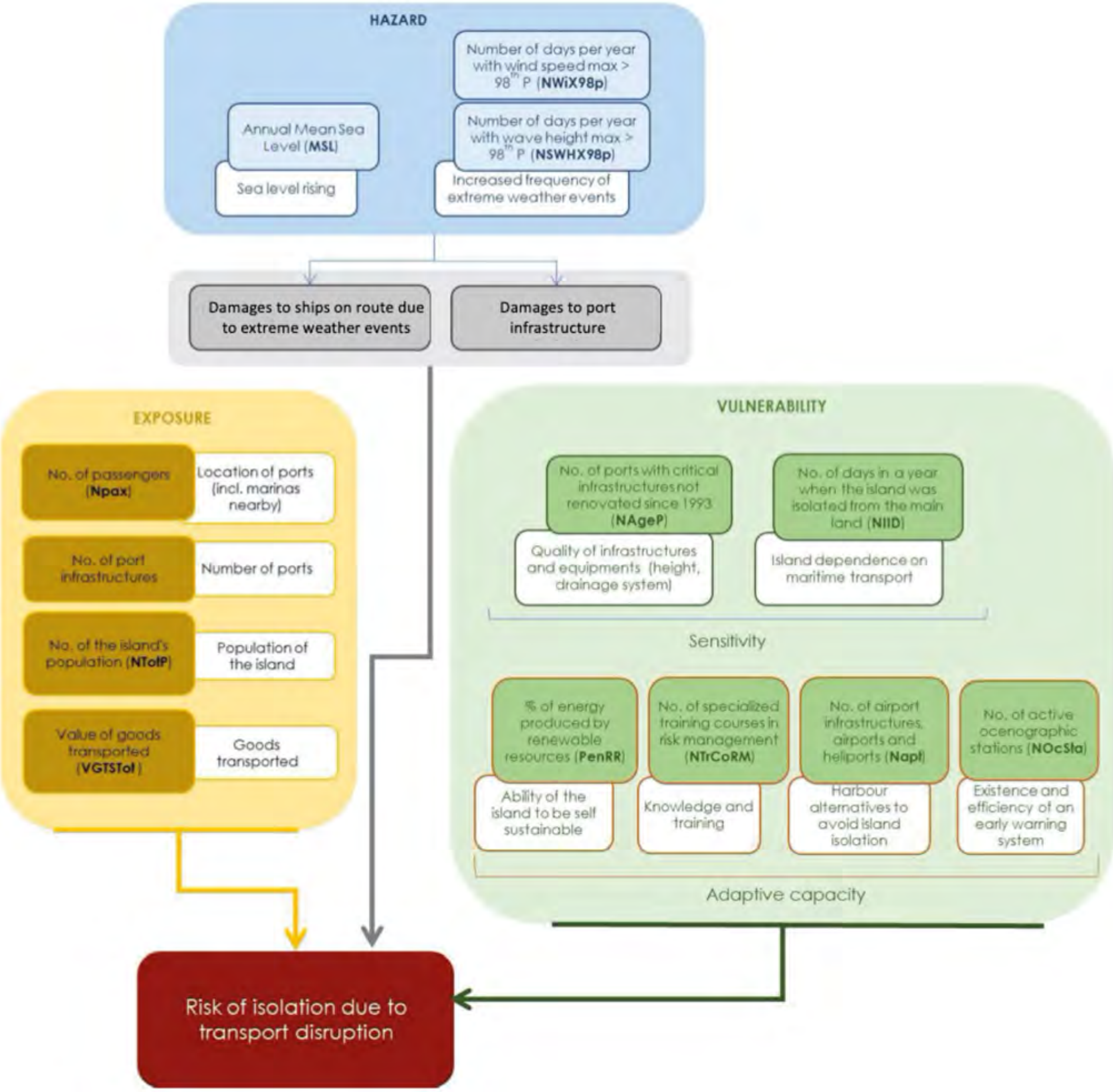


Figure 39. Conceptualization framework for the operationalization of the Maritime Transport Impact Chain: Risk of Transport Disruption.

Appendix K: Glossary of Adaptation Measures for the Tourism Sector

Vulnerability Reduction	
Public awareness programs	Establish targeted programs that raise awareness about climate change (specific values and protection needs) among guides, site managers and local communities.
Activity and product diversification	Actions to diversify the tourism activities and products and aim to reduce seasonality and overload in infrastructures and ecosystems.
Economic Policy Instruments (EPIs)	Incentives designed and implemented with the purpose of adapting individual decisions to collectively agreed goals. Different type of instruments: pricing, environmental taxes, subsidies, trading, and voluntary agreements.
Financial incentives to retreat from high-risk areas	To retreat or relocate settlements, infrastructure and productive activities from the original location due to their high exposure to floods, sea-level rise and storm surges.
Beach nourishment	Artificial placement of sand to compensate for erosion. Maintaining beach width (for tourism and recreation).
Desalination	Removing salt from sea or brackish water to make it useable for drinking, and can contribute to adaptation in circumstances of current or future water scarcity problems.
Tourist awareness campaigns	Target behavioural change of visitors and aim to increase tourists (individuals and organisations) knowledge about climate change and the risk faced by destinations.
Local circular economy	Economic system aimed at eliminating waste and the continual use of resources for reduced carbon emissions from materials and increased resilience to climate change.
Local sustainable fishing	Promotion of fishing zones/rights for local small-scale fishers maintaining stocks and using sustainable methods. Adding value to local resources and products, protect ecosystems services and decrease external dependency.
Water restrictions, consumption cuts and grey-water recycling	Restrictions of certain uses of water to allow water administration services to cope with water crises. Grey-water recycling reuse to cover water use needs that do not demand such a high-quality.

Disaster Risk Reduction	
Drought and water conservation plans	To reduce the economic, social, and environmental consequences of drought and water scarcity, reduce the loss of water and improve efficiency in the sector.
Coastal protection structures	Different types of artificial structures designed to protect the coast from sea level rise or storms.
Health care delivery systems	Pre-emptive actions and adjustments, namely reinforcing less prepared aspects of its operation and/or logistics, in order to guarantee effectiveness and efficiency.
Pre-disaster early recovery planning	The development of knowledge, good practices that aim to improve the living conditions of the affected communities, while facilitating the adjustments necessary to reduce the risk of future disasters.
Post-disaster recovery funds	Minimize the economic and social impacts (which may include future loss of the touristic destination attractiveness) that can occur in a Post-disaster context.
Mainstreaming Disaster Risk Management (DRM)	Plan and organize DRM along five stages including prevention, protection, preparedness, and response, recovery and review.
Using water to cope with heat waves	A set of investments in water supply services and infrastructures that aim to increase urban resilience regarding heat waves.
Fire management plans	Actions with a wide range of application such as early warning detection, escape routes and advice to citizens and tourists, mobilization and suppression of unwanted and damaging fires, or use of fire to manage fuel.

Socio-Ecological Resilience	
Monitoring, modelling and forecasting systems	Information system that provide timely and reliable climate information, up-to-date data on the occurrence and severity of extreme events, possible impacts and their duration.
Adaptation of groundwater management	Conserve groundwater reservoirs, limiting water use and optimizing water reuse, and restore or increase natural infiltration capacity.
River rehabilitation and restoration	Emphasise the natural functions of rivers and create vegetated buffer zones alongside watercourses. Improving micro-climatic conditions, reducing run-off and erosion, and increasing groundwater recharge.
Dune restoration and rehabilitation	Strengthening of the flood safety and sand reservoir functions of dunes. Erosion happens as a result of wind action, marine erosion, human activities and SLR.
Ocean pools	Seawater pools located by the sea where waves can wash into the pool. These recreational structures are useful on SLR context, doubling as an additional protection of the coast and creating alternatives to beach leisure areas.
Adaptive management of natural habitats	Preservation of ecosystem services which are essential for human well-being.

Local Knowledge	
Adapt tourism promotion to Climate Change risks	To maximize opportunities for tourism development, adjusting the promotional offer to climatic scenarios, namely at the level of the forest landscape mosaic and nautical tourism.
Define protection regime for "Maximum Infiltration Zones"	It is intended to adapt the regime of uses and activities to be applied to strategic areas of protection and recharge of aquifers.
Improve Natura 2000 habitats – terrestrial, coastal marine	Create new protected areas or ecological corridors and restore/ protect habitats considering the climate change risk.
Create water storage reservoirs to ensure water availability	Maximizing water storage capacity without increasing pressure on resources will allow greater resilience in times of scarcity without affecting water resources.
Adapt agroforestry systems to drought conditions	Increase and improve the water supply systems to farms, considering the installation of water meters and the application of fees / tariffs.
Distributed electric grids powered by renewables	Develop distributed electric grids based on renewable sources (photovoltaic, wind) to power desalination plants and tourist firms consortia, to reduce electricity cost and emissions, and increase the stability of the general electric grid while increasing renewables participation in the electric mix.
Zero sewage discharge to the sea	Enhance sewage treatment system: (1) mitigate the impact of seawater heating on the seagrass meadows, and (2) contribute to water supply with a lesser energy-demanding water source than desalination.
Forest fire prevention	Incentivise forest traditional cattle-based and farming activities in the periphery of forest masses uses to reduce forest flammability, performing as firewalls. Social abandon of traditional uses and upper-land agriculture lead inextinguishable forest fires.
Thermal isolation of buildings	Funding and technical assistance for the adoption of bioclimatic architecture criteria in reformed and newly built tourist buildings; regulation forcing it should be delivered together with economic incentives, socially justified by the positive externality of contributing a more environmentally friendly image of the destination.
Residual organic matter composting	Sewage sludge, organic waste from agriculture and the organic fraction are currently disposed in poorly managed landfills, releasing methane. Composting would contribute to decarbonization and landscapes rehabilitation.
Rehabilitation and conservation of islands natural habitats	In islands, habitats rehabilitation, conservation and monitoring actions, including control of non-indigenes species, are important measures to increase ecosystems resilience to climate change, in order to preserve habitats, biodiversity, landscape and key assets for tourism, agriculture, fisheries and food security.
Control measures for terrestrial and maritime tourist activities	Climate change can originate higher pressures on natural ecosystems. For that reason, additional measures could be necessary to protect those ecosystems from some touristic activities, including regulations and normative instructions in order to ensure sustainable development of terrestrial and maritime tourism activities.
Increase knowledge and modelling tools on climate change	Support downscaling climate modelling and ensure reliable systematic climate data collection is important to face islands additional constraints and support decision making processes and resources allocation for climate change adaptation.
Diversification of economic activities to reduce the dependence from tourism	Climate change extreme events can cause disruption on tourism activity. For that reason, it is important to diversify the island economy to increase resilience of socio-economic systems.
Implement waste reduction and management procedures	In islands, highly dependent from goods importation, waste reduction and waste management regulations and procedures should be implemented to reduce waste production, increase waste selective collection for recycling and decrease pressure in natural habitats that will be under stress by climate change.

Appendix L: Glossary of Adaptation Measures for the Maritime Transport Sector

Vulnerability Reduction	
Social dialogue for training in the port sector	Training into social and educational issues related with the gender equality and attracting the young to the sector, while tackling climate change. Facing how the industry is adapting to change and preparing for the future.
Awareness campaigns for behavioural change	Increase individuals and organisations' knowledge about climate change and the risk faced by the maritime transport sector.
Financial incentives to retreat from high-risk areas	Relocate settlements, infrastructure and activities from the original location due to their high exposure to flood, sea-level rise and storm surges.
Insurance mechanisms for ports	Risk-sharing schemes that aim to assist port operators in responding to the climate risks they are enabled to reduce. Insurance outsources the risks to a third party in exchange for a regular financial compensation.
Increase operational speed and flexibility in ports	Increase the attractiveness of ship transport in order to capture more freight and passenger movement. Faster operations also reduce the effects of heat waves on goods and people as well as decarbonise the economy.
Diversification of trade using climate resilient commodities	To reduce dependency on trade of perishable goods and critical services, create larger stocks of goods that are climate resilient and consider whether is economically feasible, strategically justifiable and equitable.
Climate resilient economy and jobs	To shift the economy and jobs towards a more climate resilient society. Perishable goods and some critical services rely heavily on the marine transport, which can be affected by unpredictable extreme weather events.
Restrict development and settlement in low-lying areas	Assure that ports are not further developed in low-laying areas exposed to sea level rise. Planning must consider the long-term potential risks.
Refrigeration, cooling and ventilation systems	Improve efficiency in order to reduce costs in warmer weather and maintain operations during heat waves. Ensuring the safety of passengers and workers, and manage goods that need low temperatures.
Sturdiness improvement of vessels	Improve the strength of vessels to sea storms while decreasing the noise and increasing efficiency. Wave-induced loads on the ship structures are a major concern in hull design process. Ship owners should prefer designs that allow for more demanding wave regimes (for instance, including the survivability to rouge waves).

Disaster Risk Reduction	
Climate proof ports and port activities	Investments that consider specific climate change projections to manage future risks in port infrastructures and improve operational safety conditions.
Prepare for service delays or cancellations	Promote the creation of new procedures, alternative options and channels to sell goods and transport passengers, as well as better communication to deal with delays or cancellations.
Intelligent Transport Systems (ITS)	Technologies that relay automated and tailored data and safety-related messages to ships, regarding climate hazards and other relevant information.
Backup routes and infrastructures during extreme weather	Create a post disaster response that ensures available alternatives when the main ports are damaged or inaccessible due to extreme weather events. It considers alternative ports and access roads.
Consider expansion/retreat of ports in urban planning	To consider the expansion or reallocation of areas for future maritime transport infrastructures due to climate change risks.
Reinforcement of inspection, repair and maintenance of infrastructure	Adapt monitoring to a new climate context. Changes in the frequency and/or intensity of storms, SLR or temperature, for example, may have impacts in infrastructure.
Early Warning Systems (EWS) and climate change monitoring	To assesses climate risks and relay that information to decision makers, companies utilities and the general public in real time. Transport operators should integrate this tool in procedures in order to protect the safety of people and goods.
Post-disaster recovery funds	The creation of recovery funds for the maritime transport sector to recover after disasters, through initiatives that get the economy up and running quickly while building-back-better. The aim is to minimize the economic and social impacts that can occur in a Post-disaster context.

Socio-Ecological Resilience	
Marine life friendly coastal protection structures	Constructed with materials that maximize the fixation of marine organisms. Reducing climate change impacts on local ecosystems, provides water waste depuration and water quality bio-indicators inside the ports.
Combined protection and wave energy infrastructures	Combines sea protection structures with wave energy production. This can create economies of scale, increase coastal protection and further decrease wave propagation inside the port during normal operations.
Coastal protection structures	Groynes, breakwaters, artificial reefs and seawalls built in the shoreline, designed to protect the coast from sea level rise or storms, can be used to, e.g., drift and trap sediments, protect from erosion, absorb wave energy, or allow navigation.
Hybrid and full electric ship propulsion	Environmentally friendly for marine life, decreases carbon emissions and can increase ship manoeuvrability, which is useful in small ports and under difficult weather conditions.
Integrate ports in urban tissue	Opening port areas to other activities, namely cultural, while gaining room in the urban landscape. This allows some port activities to be pooled from low-laying areas while leisure and cultural activities can access more waterfront space.
Ocean pools	Ocean pools are situated by the sea where waves can wash into the pool. The width, length and depth of ocean pools varies and often depends on their location on the coastline. These recreational structures are a response to SLR, protect the coast and create alternatives to beach leisure areas.

Local Knowledge	
Strengthen coastal protection, giving priority to the maintenance	Climate scenarios point to an increased probability of occurrence of extreme weather events. As part of the POOC review, the adequacy of the protection response must be assessed and the degree of resistance of the existing works evaluated, establishing adequate needs of maintenance, adaptation or construction.
Evaluate and plan retreat of buildings/ infrastructures from risk	Relocation of buildings or infrastructures in risk areas in case of greater vulnerability. Developed within the territorial management instruments, managing relocation through cost-benefit analysis.
Strengthen coastal monitoring	Monitoring coastline phenomena such as erosion, overflow/flood, and instability of the cliffs, which generate risk situations for people and property, considering the scenarios of climate change for medium- and long-term horizons.
Development of an adaptation plan to adequate infrastructure to climate threats	Adapt mooring structures, increase of dikes and the free board in old docks, particularly to the rise in sea level, so as to enable the Balearic Islands to maintain and improve their position in international recreational boating and recreational cruise traffic. Also to the importance of freight traffic.
Strengthen and prepare the provisioning system to heat waves	To reinforce and improve, in the face of possible climatic events, in particular to heat waves, the storage areas. Adapt the provisioning system to heat waves.
Improve monitoring systems	Monitoring systems can be improved by identifying operational working windows in case of extreme events.
Adaptation of recreational marinas to the main climate change hazards	To stimulate, accompany and encourage the adaptation of recreational marinas to the main climate change hazards, in order to guarantee the operation and future expansion of recreational sailing.
Adapt infrastructure to climate threats	Especially the electrical connection to ships during the stay in port (cold ironing), to climatic threats, and particularly to the rise in sea level.
Adaptation of recreational marinas to the main climate change hazards	To stimulate, accompany and encourage the adaptation of recreational marinas to the main climate change hazards, in order to guarantee the operation and future expansion of recreational sailing.
Improve and ensure operational safety in ship repair	Against climatic events, including shipyards and workshops with deep-sea repair capacity.
Increase knowledge and modelling tools on climate change	Support downscaling climate modelling and ensure reliable systematic data collection to support climate change adaptation strategy.
City ports as coastal protection infrastructures against extreme climate events	Future interventions in ports should take into consideration their potential to protect turban coastal areas from sea storms combined with sea level rise.
Specific requirements to increase climate change resilience	Disadvantages of islands and archipelagos regarding climate change assessment must be considered, as adaptation measures and allocated resources should deal with higher uncertainty.
Prepare islands ports to supply alternative fuels and electricity	Ports must be prepared to supply natural gas, biogas, hydrogen and electricity, in order to supply docked vessels with electricity from renewable sources, reducing the dependence from fossil fuels.

Appendix M: Glossary of Adaptation Measures for the Energy Sector

Vulnerability Reduction	
Green jobs and businesses	Training people and supporting green businesses to implement energy solutions across the economy, both in mitigation and adaptation.
Financial support for buildings with low energy needs	Loans, subsidies or tax reliefs to support the reduction of energy needs of new or existing buildings. For example, construction materials that rely on passive thermal comfort.
Financial support for smart control of energy in houses and buildings	Allows for an efficient and automated use of energy that enables savings and creates synergies with utilities. This will allow for the adaptation of buildings at a controlled cost, while complying with mitigation goals.
Demand Side Management (DSM) of Energy	An operational strategy that better coordinates producers and consumers of energy. More renewable energy use is possible while ensuring the energy service reliability and controlled costs.
Seawater Air Conditioning (SWAC)	An alternate-energy system design that uses cold water from the deep ocean to provide more efficient, decarbonized and reliable cooling. Other subsequent or parallel seawater uses can be combined, for swimming pools or desalinisation.
Small scale production and consumption (prosumers)	To promote cooperation by creating economies of scale both in the production and consumption of energy. This allows for a greater use of local renewable resources and waste energy.
Risk reporting platform	To promote the communication between the general public and the administration bodies concerning the risks related with climate change. It is a platform were the general public reports directly the risks as they become aware of.
Energy storage systems	Provide an alternative when the main power sources fail and need time to recover. This allows for a more resilient energy grid while enabling decarbonization and peak levelling at a controlled cost.
Public information service on climate action	Provide the general public with information about adaptation and mitigation options available for their activities and businesses.
Collection and storage of forest fuel loads	Promote and regulate the collection and storage of wood and combustible material to reduce wildfire hazard. Materials collected can be used in energy to waste applications such as pellets, biogas or other energy solutions.

Disaster Risk Reduction	
Review building codes of the energy infrastructure	Aims to climate-proof the energy system by reviewing regulatory codes and infrastructures considering the spatial distribution of climate risks.
Energy-independent facilities (generators)	Make it possible for buildings to temporarily create their own energy supply. In case of an energy supply failure, essential amenities remain functional and can be optimized with Combined Heat and Power designs and others.
Local recovery energy outage capacity	Increasing and improving the ability of the islands to recover from energy outages caused by, or worsen by, climate extreme events, like severe sea or windstorms that can lead to island isolation and exacerbate logistical hurdles.
Early Warning Systems (EWS)	An information system that assesses climate risks and provides real time information to decision makers, companies, utilities and the general public. Using this data to monitor the evolution of climate related impacts in the energy sector increases the knowledge necessary to make long term climate adaptation decisions.
Grid reliability	Grid reliability improvement aims to find and upgrade critical components and to enhance the energy system resilience to climate risks.
Upgrade evaporative cooling systems	Upgrade of evaporative cooling systems that rely on a given range of air temperature and water availability is necessary given that this type of cooling systems are a technology that can be affected by climate change and become compromised due to heat waves and water scarcity.
Energy recovery microgrids	Operational elements of the energy grids that rely on distributed generation to restore systems from power outages and to stabilize the grid.
Study and develop energy grid connections	Develop interconnections between islands and/or with the mainland allowing for the creation of economies of scale, energy system reliability improvements and more Renewable Energy Sources penetration.

Socio-Ecological Resilience	
Energy efficiency in urban water management	Is the adaptation of urban design and construction for water conservation that avoids energy use under scarcity scenarios. For instance, Water Sensitive Urban Design (WSUD) aims to plan water conservation and storm water storage with integration with elements of urban design.
Biomass power from household waste	Biomass power plants burn household waste, waste from parks and public gardens and sludge generated by sewage treatment plants, producing biomass for co-generation (Combine Heat and Power) as well as tri-generation (Combined Cold Heat and Power) plants.
Urban green corridors	Urban green areas decrease the air temperature in a city, and thus decrease energy needs. Creating green corridors also promotes biodiversity, increases the touristic value and decreases water run-off during storms.
Educational garden plots	Sites where people, especially children, can garden with volunteers one afternoon a week after school. This creates well-being while having local fresh produce reduces the energy consumption and pollution. These garden plots can be further exploring to educate people about other climate action measures.
Underground tubes and piping in urban planning	Used for space heating/cooling across the globe and are more resilient to climate change. These systems can be Earth Air Heat Exchanger (EAHE) and Ground Source Heat Pump (GSHP) types. Both systems use tubes or pipes that usually need to be buried beyond the footprint of the building or house.
Heated pools with waste heat from power plants	Power plants need cooling and their waste heat can be used in swimming pools for public use and tourism, called Combined Heat and Power (CHP). Pools provide a heat sink for the power plants which increases efficiency and is useful during heat waves.

Local Knowledge	
Develop risk maps for the electrical infrastructure	Develop maps to better protect and identify climate risks in the infrastructure (production, transport, and distribution centres) and plan expansion or changes in the infrastructure.
Assess and map impacts caused in quality and power reserves	Evaluate and map FER production and the impacts associated with unfavourable climatic patterns to production. It can be also used to identify additional effort or actions to regulate quality and power in the present and for the future.
Promotion of domestic and small-scale photovoltaic solar energy	Massive promotion through various instruments: a) Direct subsidy of installations; b) A more favourable legislation than the current one for the net balance; c) Massive development of energy communities in all the public and private buildings to be adapted.
Mass development of the public transport network powered by renewable energy	Make it much more effective and useful for citizens, in order to encourage its use. In particular, to develop the railway network (tramway networks), taking advantage of the existing infrastructure of the old railway network.
Promoting storage systems for renewable energy installations	This measure would seek to solve / diminish surplus problems. The strategic importance of facilitating a proper integration of renewables, particularly photovoltaic energy, with the aim of promoting decarbonization in the islands.
Hydrogen as energy vector	Using the renewable effluents for hydrogen production, the hydrogen could then be used after storage in high-pressure tanks as vehicle fuel, especially for heavy mobility.
Renewable technology hybridization	Hybridize more expensive technologies but with greater capacity to manage or provide ancillary services with less expensive but more unstable technologies. Balances the electrical system and guarantees quality supply.
Micro smart grids	Incentive providing greater resilience, since in the event of possible power failures in the electrical system, they will always have a guaranteed power supply. They serve to facilitate the penetration of the autogeneration REE in establishments, guaranteeing quality and security in the electrical supply.
Promote cogeneration	To cover the deficit in self-consumption by installing conventional back-up groups in tourist establishments, to satisfy peaks in demand for various forms of energy (electricity + heat), through efficient generators powered by fossil fuels.
Low and high enthalpy geothermal energy	Support for investment in research to determine whether the site is suitable for geothermal energy. The low enthalpy is very appreciated in air conditioning for its stability, and low cost in favorable circumstances. The high enthalpy gives stability to the electrical network.
Minimize islands energy dependence from imported fossil fuels	Energy efficiency and renewable resources potential are key assets in islands to increase resilience to climate change and to reduce dependence from fossil fuels.
Implement electricity prices for renewable energy	Differentiated electricity tariffs for renewable energy production on islands with non-interconnected energy systems that take into consideration the additional costs of investments in islands territories.
Diversification on energy supply and electricity generation	To reduce the vulnerability of energy supply and electricity generation is important to have a balanced diversification of energy sources, renewable energy sources that may be affected by climate change events and fossil fuels needed to ensure the security of supply.
Promote electric mobility integrated in smart grids	Transition from Internal Combustion Engine (ICE) to electric powertrains followed with a capable charging infrastructure with smart-charging, and V2G (Vehicle-to-Grid) functionalities.

Appendix N: Glossary of Adaptation Measures for the Aquaculture Sector

Vulnerability Reduction	
Tax benefits and subsidies	Financial public policy instruments to promote or benefit economic or aquaculture sustainable practices and operator's overall resilience to climate change.
Awareness campaigns for behavioural change	Aim to increase the knowledge of individuals and organisations, it could also be relevant in a region affected by a particular climate threat, groups of stakeholders, and the general public.
Submersible cages	Submersible cages are oceanic depth-adjustable and can be moved up and down in the sea to escape the worst effects of storms, parasite outbreaks, surface algal blooms and to keep species at an optimal temperature.
Addressing consumer and environmental concerns at the local level	This option aims to promote economy and jobs to address the future challenges of climate change. The major challenges need to be underlined and linked to the key concerns and impacts on the aquaculture sector.
Short-cycle aquaculture	Shortens the farming period and the time in marine cages by stocking larger fingerlings in the nursery stage (land-based) or selecting species with a shorter culture cycle.
Efficient feed management	Practices that reduce the Food Conversion Ratio by using technology to feed more efficient helps to reduce the cost of production and increase environmental standards
Financial schemes, insurance and loans	Public or private risk-sharing mechanisms that aim to support farmers to respond to loss of production and infrastructures damages due to extreme weather.
Recirculation Aquaculture Systems (RAS)	Land-based indoor fish farms with closed containment rearing systems where filtration is applied to purify and regulate water parameters and remove toxic metabolic wastes of fish. Since it is land-based and indoor, it limits the risk of infrastructure destruction due to extreme events in the ocean.
Promote cooperation to local consumption	Promote local consumption of aquaculture produced fish specially in tourist sector will reduce the cost of distribution and will improve the creation of add value in local products or by-products in innovative industries.
Integrated multi-trophic aquaculture	An ecosystem-based approach to culture species from different trophic levels (fish, shellfish, seaweeds) in an integrated farm to create balanced systems for environmental sustainability. In addition, it can increase resilience.

Disaster Risk Reduction	
Climate proof aquaculture activities	Investments that consider climate change projections to manage future risks to infrastructures and improve operational safety conditions, e.g., strengthening mooring systems, cage structures and nets.
Risk-based zoning and site selection	Taking into consideration climate change scenarios when planning and selecting a site for a farm, e.g., marine cage operations should not select a site that is (or is expected to be) exposed to high waves or strong currents; pond farming operations should select sites with low risk of flooding.
Disease prevention methods	Preventive health measures such as vaccines, stronger fingerlings, probiotics, ensuring optimal water quality and implementing stricter hygiene procedures with the aim of reducing the risk of diseases now and in the future.
Mainstreaming Disaster Risk Management	Plan and organize DRM considering climate change along five stages: prevention, protection, preparedness, and response, recovery and review in the aquaculture decision making and management frameworks.
Contingency for emergency management, early harvest and/or relocation	Moving activities to sites with more suitable characteristics to protect them against climate hazards (storms, high waves, temperature changes or water quality degradation).
Recovery Post-disaster plans	Establish early recovery good practices and objectives. This option will allow to reduce socio-economic and environmental consequences of the disaster.
Recovery Post-disaster funds	Create recovery funds and plans for Post-disaster in aquaculture with initiatives to get the economy running quickly. This option minimizes the economic and social impacts that can occur in a Post-disaster context.
Environmental monitoring Early Warning Systems (EWS)	Systematically collect and provide information to fish farmers with the aim of supporting climate risk management. Monitoring and early warning facilitates adaptation actions: early harvesting or relocation of fish net pens from sites of intense harmful algae blooms.

Socio-Ecological Resilience	
Feed production	An important indirect impact to aquaculture is the change in fisheries production due to climate change. Aquaculture of finfish is highly dependent on fisheries for feed ingredients. This is already a current problem with many fisheries overexploited and will only intensify in the future. Therefore, alternative feed ingredients are being developed such as insect meal and algae.
Species selection	Selecting species that are less sensitive to changes in the environment, less prone to diseases and less dependent on fish meal and oil.
Selective breeding	Genetic selection of species with a focus on developing strains with a higher tolerance to changes in temperature, that grow faster, and which are more resilient to diseases. For example, choosing species with a wider temperature tolerance range may reduce the risk of future mortality.
Best management practices	Implementing best management practices at farms which focus on food safety, fish health, environmental impact (including climate change) and social responsibility.
Create educational visits	Students, schools, institutes and organisations can organise visits to the fish farms to learn about aquaculture and the interactions between aquaculture and the environment. These visits can also increase knowledge on different impacts on aquaculture including man-made and climate impacts
Promote aquaculture cuisine	Promote aquaculture via online information and uses local restaurants. Aquaculture itself can be seen as an adaptation measure to climate change and as an alternative to wild fisheries, which production and yield will reduce due to climate change. Therefore, promoting aquaculture species in restaurants or setting up specific 'aquaculture' restaurants will provide both a cultural experience and promote farmed products.

Local Knowledge	
Increase POSEI and REF incentives	Increase incentives that compensate for the distance and insularity in the POSEI and the REF, as well as guarantee viable commercial margins, which will be affected by climate change.
Promote tourist and non-tourist consumption	The increase in consumption on the islands helps to reduce emissions, enhances the km 0 concept, contributes to the development of food sovereignty with high quality protein, and strengthens social cohesion.
Knowledge transfer and financial support of emerging industries	Optimize the transfer of knowledge from research groups to the industry, aimed at enabling local production of raw materials and juveniles, and the introduction of new species more resilient to climate change and its effects; also, financial support scheme to this industry until it reaches the optimal scale.
Reformulate the POEM (Zoning)	To address the impact of climate change, the criteria for determining areas to be used in the future need to be improved and expanded: planning. Increasing depth reduces impact, improves habitats, and increases production.
Review and streamline administrative processes	Improving governance is key to addressing the impact of climate change. Reviewing and streamlining administrative procedures will help minimize the impact on production volumes.
Favour the development of off-shore aquaculture	It means an increase in the area of innovation, technological change to introduce a cultivation system that does not exist on the islands. It improves the resistance to catastrophic weather episodes as a result of climate change and consequently contributes to reducing the environmental impact, favouring an increase in production.
Aquaculture as an alternative to fishing	Jobs offer and training programmes for fishermen who left decommissioned fishing boats; adaptation of fishing boats into aquaculture service boats.
Long-term environmental data collection and management	Establishment of long-term standard monitoring systems, integrating climate, oceanography and environmental data.
Implementation of local sanitary programs at regional scale	Long-term stock health surveys, disease control and eradication.
Implement measures for increasing local industry self-sufficiency	Providing higher autonomy and selfcare of the industry with production of local "seed" with strains of higher adaptability to local climate changes.
Aquaculture and circular economy	Integrate aquaculture in circular economy to take advantage of potential local wastes regarding energy, fish industry discards and wastes, distribution and marketing systems, etc., diminishing the ecological footprint.

The **SOCLIMPACT Project** was funded by the **European Union´s Horizon 2020** research and innovation programme (GA 776661), and carried out by a consortium of 24 partners from 9 European countries.

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