Angela Santangelo

Energy behaviour-driven strategies for urban regeneration

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Questo volume è stato pubblicato grazie al contributo del Dipartimento di Architettura, Alma Mater Studiorum - Università di Bologna / The publication of this book has received fundings from the Department of Architecture, Alma Mater Studiorum - University of Bologna

Il presente volume è stato oggetto di una procedura di accettazione e valutazione qualitativa basata sul giudizio tra pari con il sistema del *blind peer review*./ This book undergo a process of acceptance and evaluation based on peer review with the system of blind peer review.

Edifir Edizioni Firenze s. r. l.
Via de' Pucci, 4 – 50122 Firenze
Tel. 05528639 - www. edifir. it – edizioni-firenze@edifir. it

Managing Editor
Simone Gismondi

Design and Production Editor
Elena Mariotti

ISBN 978-88-9280-150-9

Cover
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››› Glossary

(in alphabetic order)

› Building renovation

Actions to retrofit, restore, rehabilitate, and renovate the existing stock, aiming at improving the energy efficiency of the buildings.

› Consumer behaviour

Set of activities that prospective customers undertake in searching, selecting, valuing, assessing, supplying and using of products and services in order to satisfy their needs and desires. It is a process which includes the issues that influence the consumer before, during and after a purchase or action. To the aim of this piece of work, consumer behaviour, user behaviour and occupant behaviour have been used indifferently.

› Energy behaviour

All human actions that affect the way that fuels (e.g., electricity, gas, petroleum) are used to achieve desired services, including the acquisition or disposal of energy-related technologies and materials, the ways in which are used, and the mental processes related to these actions.

› Energy poverty

Energy poverty, also known as fuel poverty, is often defined as a situation where households cannot access to and afford adequate level of heating or other required energy services to meet their basic needs, or they cannot afford other necessary goods due to the high utility costs. It is a growing phenomenon in European Union, with more than 150 million people with more of 10% of their annual income spent on energy services.

› Energy Service Company (ESCo)

For-profit or non-profit organisation specialised in providing a range of energy services to their clients. It promotes energy efficiency and water consumption reduction on the premises of their customers. The building occupants then benefit from the energy savings and pay a fee to the ESCo (e.g., usually a higher energy bill than actual consumption, but still lower than the one prior renovation) for the whole payback period.

› Occupant behaviour
Observable actions or reactions of a person in response to external or internal stimuli, or respectively actions or reactions of a person to adapt to ambient environmental conditions such as temperature, indoor air quality or sunlight. To the aim of this piece of work, consumer behaviour, user behaviour and occupant behaviour have been used indifferently.

› Policy instrument
Tool used by government/public authorities in local, national or international context to pursue a desired outcome. Throughout the book it is used to refer to different tools (e.g., energy policy or strategy, urban planning tool, building regulation tool, informational campaign).

› Prebound effect
Households using less energy than foreseen due to energy poverty condition and low awareness of energy efficiency technology use.

› Pro-environmental behaviour
Intentional behaviour that harms the environment as little as possible, or reduces the environmental impact relative to comparable behaviours.

› Prosumer
Active energy consumer who both consumes and produces energy from microgeneration.

› Public housing
Housing stock publicly owned for households whose needs are not met by the market and where there are rules for allocating housing to benefiting households, paying a rent far below the market one. Throughout the book, it is considered as a subset of the social housing.

› Rebound effect
Increase in household energy consumption as a consequence of paying less attention to the energy-related behaviour after the energy measures implementation, since there is a general belief that the increase of energy efficiency in buildings should automatically be translated into a decrease of consumption, no matter the level of usage and behaviour.

› Social housing
Throughout the book, it is considered as an asset mostly coincident with the public housing, for households whose needs are not met by the market and where there are rules for allocating housing to benefiting households, paying a rent far below the market one. To clarify the ambiguity around the Italian terms for public housing *(Edilizia Residenziale Pubblica)* and for social housing *(Edilizia*

Residenziale Sociale) is out of the scope of this research, which considers the term social housing with the meaning generally recognised at EU level.

› Urban regeneration

Urban regeneration is considered throughout the book as a set of regeneration actions, policies and processes with a city, district or neighbourhood scale addressing interrelated technical, spatial and socio-economic issues towards the reduction of environmental impact, mitigation of environmental risk and improvement of environmental quality of urban systems, lifestyles and assets.

››› Preface

by Simona Tondelli

The global world is facing an unprecedented energy crisis because of the extraordinarily rapid economic rebound following the pandemic and, lately, Russia's invasion of Ukraine.

Higher energy prices have contributed to high inflation and slowed economic growth to the point that some countries are heading towards severe recession. Some gas-intensive manufacturing plants in Europe have curtailed output because they can't afford to keep operating, while local authorities are switching off lights at public monuments and turning off heating at city run buildings like leisure centres. The crisis has ratcheted up heating bills, resulting in an unprecedent increase of the number of people affected by energy poverty and set back progress towards achieving universal and affordable energy access.

The energy crisis set off by Moscow's war is urging governments to deeply rethink energy policies, from production to consumption. The International Energy Agency (IEA, Coal 2022 report) estimates the EU's coal consumption rose by 1.2% in 2022, surpassing 8 billion tonnes in a single year for the first time and eclipsing the previous record set in 2013. This unexpected rise in coal burning appears to contradict the EU's stated priorities for COP27 and risks to jeopardize the goals already set towards climate neutrality.

While urging countries to promote renewable energies and the development of energy efficiency, short term measures include reduction actions to cut electricity and gas consumption and preserve stocks.

Being responsible for 30% of total global final energy consumption and 27% of total energy sector emissions (EIA, 2022), buildings are a key sector when it comes to addressing high energy prices and security of supply concerns.

To this aim, the rate of renovation should be increased, particularly for the worst-performing buildings in each country, to modernise the building stock, making it more resilient and accessible. However, as Santangelo clearly explains in the first chapter, "the energy efficiency process, to be effective in achieving energy reduction targets, should be conceived as a part of an integrated and broader urban strategy fostering urban regeneration of the existing city, where the local authorities have a key strategic role in coordinating and influencing the activities of a range of actors, in defining areas and communities to focus on, and in engaging people in changing behaviours in order to reduce energy consumption". Therefore, nowadays it is even more important than before to focus on households' contribution to energy savings.

Within this book, households' contribution to energy savings has been investigated with reference both to the occupants and to the energy-related behaviour of key stakeholders (chapter 1), as a prerequisite to achieve the goals set at international level by the Paris Agreement and affecting national energy policies.
In the framework of the actual energy crisis, the analysis of the extent to which consumer behaviour, building renovation and urgency to take actions on public buildings are embedded in the energy and sustainable development policies is even more important and can provide insights for acting rapidly towards climate neutrality.
After analysing existing knowledge on household behaviour determinants and strategies to promote behavioural change (chapter 2), the author demonstrates that the gap between expected and actual energy consumption in buildings is highly dependent from the human factor (chapter 3). Indeed, the application of a methodology based on multi-criteria assessment of different strategies by applying the Analytic Hierarchy Process (AHP) shows that even the deepest level of retrofit is not able to obtain the expected results in term of energy consumption reduction if it isn't accompanied by soft measures acting on occupant's behaviour.
The book offers an innovative approach to occupant's behaviour impact on energy savings, going beyond the traditional approaches form economists, sociologists, or architects. In fact, the author suggests adopting an urban planning perspective, claiming that it is necessary to embrace holistic policies able to integrate the different measures within a comprehensive urban strategy and making people the main actors of energy transition. Moreover, according to Santangelo, there is the need for a more accurate knowledge of the current situation to choose the effective mix of actions to be implemented in order to carry on a comprehensive policy for achieving the reduction of energy consumptions. On the contrary, data about energy consumption are still scarce and mainly available in aggregated form or as average; there is a lack of transparency that makes it difficult to undergo detailed forecasts with reference to the goals that it is possible to achieve through the implementation of one or another measure.
This publication highlights the need of a public actor able to be the director of the energy transition process, by fixing priorities and activating changes through the careful and knowing use of public incentives, and by inverting the paradigm according to which energy utility companies benefit from families' consumption instead that from their savings. The research presented in this book is particularly useful for guiding planning policies, because it underlines the importance to involve in the decision systems all the different actors, from energy utilities, to owners and tenants, and to local authorities.

››› Introduction

Nowadays, the urban environment is considered to be a key player in the management of climate change related issues. Urban sprawl, over-consumption of energy, release of CO_2 emissions, deployment of natural resources, dependency from fossil fuels and waste production are among the main concerns of public authorities managing the public goods, increasingly looking for more effective ways to implement sustainable development without deploying the natural resources.
In terms of size, cities occupy only 2% of the world's land (Timothy 2003). However, in terms of climate impact, they are responsible of a far bigger footprint. Cities consume over two-thirds of the world's energy and account for more than 70% of global CO_2 emissions. When it comes to Europe, hosting more than 75% of the European population, cities have a prominent role in the mitigation and adaptation processes to climate change. Therefore, improving energy efficiency in all sectors has been a major concern in the European context.
In order to pursue together social, economic and environmental goals, energy-related issues should be embedded within the urban planning process (Gargiulo and Russo 2018). Local authorities, responsible for implementing urban planning tools and strategies, are the one able to lead to the urban transformations required to face climate change and energy efficiency challenges (La Greca and Martinico 2016; La Greca and Tira 2017). To this aim, innovative spatial and urban planning methods and procedures are required, as well as new approaches and instruments must be elaborated to shift from the building scale to the urban and territorial ones (Zanon and Verones 2013; Tira et al. 2017).
Besides being a multi-scale issue, facing energy and climate challenges is a horizontal priority for different sectors and societal domains (Papa et al. 2016). Among them, the key role of the building sector has been clearly recognised in energy consumption and environmental impact. Worldwide, the residential sector consumes an amount of energy that varies between 16% and 50% of the total, depending on the country (Filippidou et al. 2016). In the European Union, buildings are responsible for 40% of energy consumption and 36% of CO_2 emissions. The residential sector, with the 75% of the total energy consumption in buildings, is an important target area for energy reduction. There is a considerable potential for energy savings in heating and cooling that remains largely untapped. Today, at global level, heating and cooling in buildings and industry account for approximately 40% of final energy consumption — which is a larger share than transportation (27%) (IEA 2017).

Thanks to the energy performance regulations at EU level and at Member State level, residential buildings have incrementally improved in terms of their energy efficiency during the last decade. In particular, looking at the residential sector, the improvement has mainly been achieved thanks to the construction of new and more efficient buildings. So far, technology innovation, buildings and construction research and development sectors have focused on passive and low to zero energy housing. However, about 75% of the residential buildings that will constitute the European housing stock in 2050 have already been built today (Visscher et al. 2016). Therefore, the renovation of the existing housing stock is a fundamental step in the path to achieve the EU targets.

The urgency to renovate the existing buildings is also embedded in the EU Directive 2018/844 amending Directive 2010/31/EU on the Energy Performance of Buildings (EPBD), the Directive 2012/27/EU on Energy Efficiency (EED), and the overarching European Green Deal, all requiring Member States to establish a long-term renovation strategy to support the renovation of the national stock of residential and non-residential buildings, facilitating the cost-effective transformation of existing stock into nearly zero-energy buildings (European Commission 2018).

While the EPBD sets minimum energy performance requirements for all the buildings that undergo major renovations, Article 5 of the EED sets a binding renovation target for public buildings and imposes related obligations. It also stresses that governments shall undertake an exemplary role in the energy retrofit of their building stock. Article 5 of the EED stipulates that, for each Member State, 3% of the total floor area of heated and/or cooled buildings owned and occupied by central government should be renovated each year to meet at least the minimum energy performance requirements. However, renovation monitoring system is poor and, so far, there are no data to assess if 3% has been reached. Hence, how to boost the renovation of existing building stock and monitor the actual energy savings still represent major challenges.

With 70% of Europe's 2050 housing stock already built, urban regeneration represents the key strategy to cope with the increasing demand of integrating sustainability principles in everyday life. Energy can be considered to be a prominent driver to address urban regeneration (Gargiulo and Lombardi 2016).

Due to the multiple and often divergent interests that characterise the urban environment, to be effectively implemented, urban regeneration requires the adoption of a multilevel governance approach. Multilevel governance has been analysed by Bulkeley and Betsill (2005) in terms of environmental and climate change governance as a possible interpretation of the changing relationships between institutional levels. The involvement of the private sector in the realisation of certain planning goals is strongly related to a very common trend characterised by governments that become less active regulators, and instead turn into facilitators of new developments that are preferably realized by the market (Verones 2013). Nevertheless, when it comes to residential buildings, the fragmentation of housing properties – typical of South-East Europe countries – represents a critical obstacle to the implementation and scalability of regeneration practices. Therefore, social housing associations with their large stock portfolios, either individually or in partnership with others, are the best arena to implement urban regeneration strategies embedding household energy behaviour (Santangelo and Tondelli, 2017a; Santangelo et al. 2018; Santangelo et al. 2021), both combining interventions to the open space and the built environment.

Despite the effort in promoting lower energy consumption in buildings, the visionary energy efficiency goals set at EU level are far to be met (Steemers and Yun 2009; Majcen et al. 2013; Yan et al. 2015; van den Brom et al. 2018) also for new buildings designed to be energy efficient, either residential buildings, or other buildings. The gap between expected and actual energy consumption, together with the impact of occupant behaviour on building energy use have been increasingly studied by scholars. Energy savings through behavioural factors can be as high as those from technological ones (Lopes et al. 2012), thus giving to the occupants the possibility either to reinforce the savings from energy efficiency measures, or to waste them.

Building regulations on energy consumption are formulated basing on building and heating, ventilation and air conditioning (HVAC) system characteristics, and make assumptions of occupant behaviour paradigm as static (Bedir 2017) and deterministic, ignoring the fact that, during the operational phase, they are people who use energy, not the building as such. Thus, building simulation models and energy renovation strategies need to be based on more realistic assumptions to take into account energy behaviour as a dynamic and stochastic variable.

Due to the large share of residential energy use in buildings, most of the research on energy behaviour has been essentially focused on the housing sector. Comfort preferences can vary across households and even across people in the same household. The control of indoor conditions (e.g., ventilation, temperature) could have a strong effect on the interaction between the household and the dwelling. Variations in preferences for comfort and indoor conditions have also been shown to depend on household characteristics and other socio-demographic variables, influencing energy consumption via differences in motivation and attitudes towards energy and environmental conservation. The relation among behavioural determinants is believed to be a key point in the formulation of policies and strategies to lower energy consumption through behavioural change.

Another key issue concerns the monitoring of energy improvements. The difficulty to quantify behaviour has contributed to limit the integration of the human factor in energy efficiency policies and building renovation strategies, with a consequent overconfidence in technology.

The above framed problems make explicit the urgency to tackle household energy behaviour as a prominent issue to effectively achieve the renovation and lower consumption of residential buildings. Many disciplines – from sociology, anthropology, psychology and economy, to building automation, data science, architecture and urban planning – can take part to suggest how to better incorporate the human factor in their core research topics.

A focus on Italy and on public housing

Increasing the rate at which existing buildings are renovated to at least 2% for private sector and 3% for public sector per year until 2030 is a key objective of the EU's Resource Efficiency agenda. However, figures for Italy resulted from a study commissioned by the European Parliament (Artola et al. 2016) show a current renovation rate below 1% of the total building stock, which confirms the data of the Buildings Performance Institute Europe (BPIE 2013).

Energy efficiency through building renovation and urban regeneration is a major challenge both in EU and in the Italian context, where building renovation can be considered as one of the strategies to achieve city regeneration, due to the fact that the built environment is embedded in all the four categories of urban features (i.e. physical, functional, geographical, socio-economic features) (Gargiulo and Russo 2017, 2018) or subsystems (Papa et al. 1995), influencing energy consumption and CO_2 emissions, as classified by scholars investigating the multidimensional relationship between cities and energy consumption.

In 2018, the energy consumption of residential sector in Italy was around 34 Mtoe, and it shows a growing trend of 1% per year. The space heating accounted for 69% of energy consumption followed by electrical appliances (13%), water heating (11%), cooking (6%) and air-cooling (1%) (Odyssee-Mure 2021).

When it comes to the housing stock tenure, home ownership is by far the most common tenure in Italy, with more than 72% of households who own their houses (Pittini et al. 2017). Social rental housing accounts for 3.7% of the total housing stock (Pittini et al. 2017). The great majority refers to public housing for rent, managed by public housing associations, which are responsible for the allocation and maintenance, while the dwellings are mainly owned by the municipalities or regional authorities (Capriotti and Santangelo 2021), and they have to comply with regional norms and regulations. Housing cooperatives and most recently foundations have also been involved in social rental housing provision. While in the owner-occupied sector cost-savings are expected somehow to be the main stimulus for building energy-efficient renovation, the interventions within the social housing stock not only have an energy-saving value, but also enhance the role of energy efficiency in combination with the social and economic co-benefits (e.g. poverty alleviation, health improvements), thus contributing to avoid stigmatisation, social segregation and to reduce fuel poverty (Santangelo and Tondelli 2017a; Santangelo et al. 2021).

The involvement of Energy Service Companies (ESCos) for the energy renovation of the housing stock through the sign of an Energy Performance Contract (EPC) has been experimented in the Italian public housing context (Santangelo and Tondelli 2017a), due to the lack of public funds, that push public authorities to increasingly look for building public-private partnerships to renovate their building stock. The ESCos bring to the public housing providers and the municipality the technical and financial services needed for energy efficiency projects (i.e. implement a customised energy service package, consisting of – among others – planning, building,

operation and maintenance). However, the uncertainness related to the occupant behaviour has limited this application, since the payback period is strongly related to the consumption patterns (Proli et al. 2016; Santangelo and Tondelli 2017a), and long payback periods make the investments unattractive. In addition, ethic issues have raised when the model is applied to the public housing sector (Santangelo and Tondelli 2017b), since the allocation of dwellings to low-income occupants is currently not taking into account the energy demand of the dwellings.
Despite the limited size of the public stock, due to the favourable situation of public housing providers having an exclusive role in public housing stock management, and the similarities in the regional regulations and procedures among providers, the public housing sector is selected as a case study for this research. Moreover, it has been chosen as the building typology is representative not only of the Italian public residential stock, but also of the Italian housing sector in general, considering that more than 70% of the permanently occupied housing stock consists of apartments. Due to the high percentage of housing units in multi-family buildings, the analysis applied in this research can lead to a wide replicability of the method to the Italian housing stock.
Public housing, social housing and housing policies have always been studied by urban planning as ways to achieve sustainability in cities. Demonstrating, prior in public buildings than in the other housing stock, the relations among stakeholders to implement energy renovation, and the relevance of household energy behaviour to effectively reduce energy consumption in buildings, could lead to a multiplier effect. Behaviour is more likely to be deliberately considered and changed when a discontinuity occurs in the household context (Huebner et al. 2013). Therefore, building renovation programmes are the key opportunity to involve households in order to make them rethinking their consumption practices. However, pro-environmental behaviour is likely to be considered if information and education measures come from credible, trustworthy sources. Thus, the impact of the renovation programmes is closely linked to the relationship between tenants and housing providers.

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››› 1.
Framing consumer behaviour in urban and energy planning

There is no single term or definition able to capture the complexity of consumer behaviour in relation to energy consumption. Depending on the discipline which investigates this topic, the terminology may vary greatly. Several definitions are available in literature and have been summarised by the “Consumer Behavior in Building Energy Use” entry as part of the Encyclopedia of the UN Sustainable Development Goals (Santangelo and Tondelli, 2021). They are reported below and constitute the starting point for this research.
Economic science describes *consumer behaviour* as a “set of activities prospective customers undertake in searching, selecting, valuing, assessing, supplying and using of products and services in order to satisfy their needs and desires” (Čavoški and Markovíc 2015). Prior to this, it has also been defined as a process, which includes the issues that influence the consumer before, during and after a purchase or action (Foxall 1993; Solomon 2006).
When it comes to energy consumption and energy efficiency, there is a lack of common understanding around consumer behaviour, due to the strong link it has with the technical, economic, sociological and psychological models applied to understand how and why people perform energy-related actions, and to the disciplines which investigate these actions. Consumer behaviour might be referred, among others, as occupant behaviour or (user) energy behaviour. Looking more specifically to the residential sector, the household behaviour is used for referring to the energy consumption caused by more than one user, while pro-environmental behaviour is mostly used as a goal to reach in case of strategies to lead to behaviour changes are applied.
Occupant behaviour has been referred as a set of “observable actions or reactions of a person in response to external or internal stimuli, or respectively actions or reactions of a person to adapt to ambient environmental conditions such as temperature, indoor air quality or sunlight” (International Energy Agency EBCP 2013). However, this definition does not take into account individual attitudes and reasons which lead to a specific action, which instead have been intensively studied in social sciences.
Energy behaviour has been defined as “all human actions that affect the way that fuels (electricity, gas, petroleum, coal, etc.) are used to achieve desired services, including the acquisition or disposal of energy-related technologies and materials, the ways in which these are used, and the mental processes that relate to these actions” (International Energy Agency DSM Energy Efficiency 2014). Energy

behaviour is the one leading to end-use energy consumption, incorporating two implicit dimensions: the behaviour itself, and the associated energy consumption (Lopes et al. 2012).
Pro-environmental behaviour has been referred to "intentional behaviour that harms the environment as little as possible, or reduces the environmental impact relative to comparable behaviours" (Wilson and Dowlatabadi 2007; Steg and Vlek 2009).
To the purpose of this work, all the terms above are assumed to embed energy consumption as subject of investigation, therefore, consumer behaviour, user behaviour and occupant behaviour are used indifferently. People spend most of their lives indoor. Considering that "home" is the place where people have the greatest control on their circumstances in their own environment, it represents a crucial point in the effort for raising awareness about the role of consumer behaviour in lowering energy consumption (Hayles and Dean 2015).
Consumer behaviour is of paramount importance for understanding both the direct and indirect impact that human preferences have on the environment. Energy use is embedded in everyday routines, mostly in a silent way. Since decisions to use energy are generally unconscious, it is difficult to deliberately decide to save energy. Nevertheless, there is a growing awareness of the need to understand the human factor as a prerequisite to achieve the goals set at international level by the Paris Agreement and affecting national energy policies, and many scholars call for inter-disciplinary knowledge and multi-disciplinary efforts to address user behaviour and thus unlock its energy efficiency potential.
The residential sector is by far the main contributor to energy consumption in buildings in EU, therefore it is not surprising that most of the research on consumer behaviour has been essentially focused on investigating the human dimension of household energy consumption.
Occupant behaviour studies have mainly aimed at explaining the gap between theoretical and actual energy consumption in buildings (Steemers and Yun 2009; Yan et al. 2015; van den Brom et al. 2018), identifying behavioural patterns and household characteristics driving certain behaviours (Van Raaij and Verhallen 1983; Gram-Hanssen 2010; Ben and Steemers 2018), supporting decision-makers in promoting energy saving behaviour (Frederiks et al. 2015). Space heating represents the largest share of household consumption (about 63% in 2020 according to Eurostat). In 2020 in EU, household consumption for space heating, water heating and electrical appliances accounted respectively for 63%, 15% and 15% of the total consumption. Occupant behaviour related to space heating has been investigated in various empirical studies, among others (Gram-Hanssen 2010; De Meester et al. 2013; Engvall et al. 2014; Ren et al. 2015; Santangelo et al. 2018). Behaviour related to electricity consumption has also gained attention in a number of studies (Grønhøj and Thøgersen 2011; Abreu et al. 2012; D'Oca et al. 2014a) while ventilation and window opening behaviour (Andersen et al. 2009; Fabi et al. 2012; D'Oca et al. 2014b), domestic hot water (DHW) (Feng et al. 2017; Mora et al. 2017) and water saving behaviour (Martínez-Espiñeira et al. 2014; Hayles and Dean 2015) have been so far less investigated. Few studies have

attempted to study many occupant behaviours at the same time (Stazi et al. 2017). In addition to this, some researchers argue that not only households and occupants, but also key stakeholders (i.e. building designers, operators, managers, engineers, industry, vendors, and policy-makers) need to be aware and educated on the relevance of the human factor to their particular perspective, in order to integrate the human dimension in their daily actions (Santangelo and Tondelli 2017; D'Oca et al. 2018).

This chapter aims to gain a greater insight into the policy framework and regulation elaborated at four levels of governance (i.e. international and EU; national; regional; local) to verify to what extent consumer behaviour, building renovation and urgency to take actions on public buildings are embedded in the energy and sustainable development policies.

Starting from an overview of social science and technological theoretical approaches to consumer behaviour, this chapter provides an insight into international and EU level policy framework, where then the Italian level is further investigated, to check the relevance of the three above-mentioned topics within the national energy strategy. Since in Italy spatial and urban planning are topic tackled by regional legislation and local codes, these two administrative sub-levels are analysed as well, providing information on the energy strategies and plans for the Emilia-Romagna Region and for the municipality of Bologna, capital city of the Emilia-Romagna Region. A comparison matrix for the analysis of the four policy levels is developed to facilitate clear trends and gaps between the policy instruments presented, and to facilitate the identification of possible future instruments needed to overcome current barriers.

1.1. Household energy behaviour: a theoretical framework

Consumer behaviour is overall influenced by both individual characteristics and the societal context. As pointed out by Abrahamse et al. (2005), the TEDIC factors such as technological developments, economic growth, demographic factors, institutional factors, cultural developments influence consumer behaviour at the broader level, while micro-level factors such as motivation, opportunity and ability (MOA factors) shape user behaviour at the individual level.

Investigating consumer behaviour towards energy efficiency and sustainable energy consumption requires a deep understanding of both the human factor and the technological asset, and the application of qualitative and quantitative methodologies. A brief review of the two main approaches – based on social science theories and on technological disciplines – is presented below and summarised in Figure 1.1. They both rely on modelling as key approach that helps explaining the reality and informing the users, while, to the aim of this work, behaviour modelling is considered an effective tool for assess scenarios and support policy-makers to take decisions on policies and strategies on energy retrofit and urban regeneration.

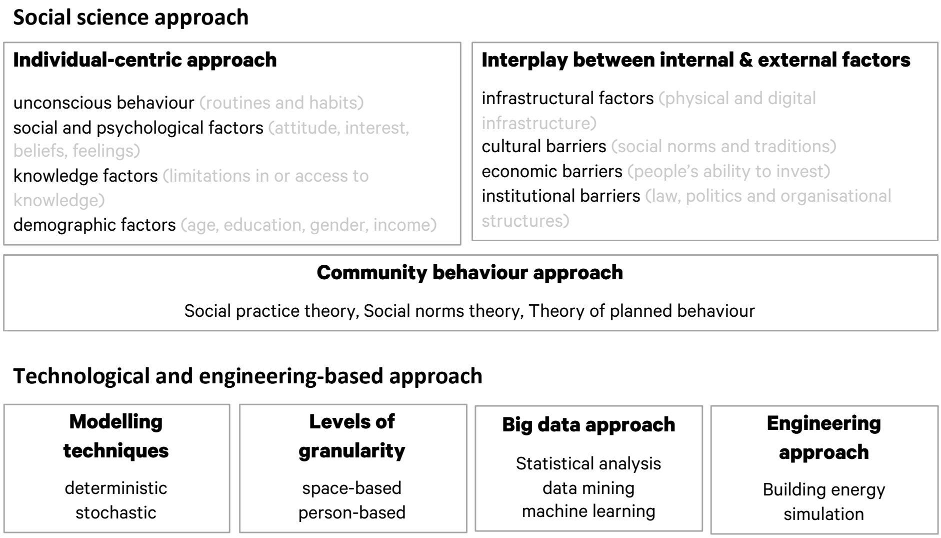

Figure 1.1. Schematisation of the main components of the social science and the technological and engineering-based approaches. Source: author's elaboration.

1.1.1. Social science approach

As reported in the "Consumer Behavior in Building Energy Use" entry as part of the Encyclopedia of the UN Sustainable Development Goals (Santangelo and Tondelli, 2021), one of the first behavioural economic theories is the utility-based decision model. It is grounded on the micro-economic theory of utility maximization given certain preferences, where consumers are assumed to behave rationally, but in order to weigh the costs and benefits of various options, they need information on the possible actions or goods they can choose from. However, after having been largely applied in the 1970s, this model has progressively been replaced by others, since it has been demonstrated that behaviour embeds a number of inconsistencies, and consumers do not make consistent rational decisions, no matter how complete the information provided is (Wilson and Dowlatabadi 2007; Lopes et al. 2012). People take decisions not only considering short-term monetary paybacks, but also assessing other non-monetary positive or negative elements, resulting in non-rational decisions.

Social and environmental psychology has started from the 1970s to explore behaviour in relation to energy efficiency of the residential sector. According to the ecological value theory, people with egoistic and self-interested values are less likely to perform pro-environmental behaviours than those who have pro-social values. However, having pro-environmental attitudes is not a sufficient condition for acting in an environmentally friendly way. The value-belief-norm (VBN) theory proposes a causality relation between personal values, ecological worldview, adverse consequences for valued objects, perceived ability to reduce threat and pro-environmental personal norms. The three causal variables that lead from values to personal norms that activate environmental behaviour are beliefs. As a consequence, information can play an important role in influencing beliefs, which in turn can change pro-environmental norms that finally lead to environmentally significant behaviours (Kowsari and Zerriffi 2011). However, decision models that exclude contextual factors often fail to adequately explain energy-related behaviour when it involves high-effort, high-cost and high-involvement decisions (Lopes et al. 2012). Hence, context has been included in the attitude-behaviour-external conditions (ABC) model, where attitudes are considered to lead to behaviour change only if contextual variables (e.g. physical, financial, legal, or social) provide either incentives or disincentives.

Moving to sociology, sociological approaches generally question the models described above, arguing that energy use is not a consequence from choices of a single person, but it results from the social context. Indeed, sociologists and anthropologists believe that human behaviour is social and collective, and that energy models that intend to include behavioural dimensions should consider the social context of individual actions. Therefore, in the residential sector, they consider the household rather than the single user.

Coming to practice theory, it focuses on the collective structures of practices and on what guides the practices people perform in their everyday lives, where energy consumption is not a practice in itself, but it is a consequence of all the different energy-related activities that people do at home (Gram-Hanssen 2010; Hargreaves 2011; Moloney and Strengers 2014; Shove and Walker 2014). The methodological approaches to study household energy consumption include survey methods, statistical analysis of large databases, qualitative interviews, indoor measurements and detailed end-use metering. However, Gram-Hanssen (2014) argued that neither of these approaches is the most useful when analysing household energy consumption, as much of consumption relates to unconscious habits and technological structures which are not very well understood in behavioural or lifestyle approaches. Practice theory is considered an approach that better includes both unconscious habits and technological structures.

1.1.2. Technological and engineering-based approach

In literature, energy modelling has been applied mostly to quantify energy consumption either to inform the building design sector, but also to support policy-makers in assessing the effectiveness of different scenarios. Focusing on the bottom-up approach (Lopes et al. 2012), rather than on the top-down approach, which is unable to distinguish individual behaviour, these models make use of input data as household characteristics and building – or group of buildings – characteristics, to assess either the energy consumption embedded in certain behaviours or to cluster the users according to recurring behavioural patterns. Behaviour models do not represent deterministic events, but help investigating occupant behaviour which is complex, with interdisciplinary characteristics (Hong et al. 2017).

Happle et al. (2018) categorised the occupant behaviour modelling approaches according to two techniques (i.e. deterministic vs. stochastic) and two levels of granularity (i.e. space-based vs. person-based). In the deterministic model, a standard day profile is usually the same for all days, with no change in occupancy schedules throughout the year. The stochastic models generate random non-repeating daily profiles of occupancy for a long-term (annual) building performance simulation, resulting in multiple building occupancy patterns to evaluate the uncertainties related to occupant behaviour (Yan et al. 2015). When it comes to the granularity, space-based approaches directly model the impact of aggregated occupant behaviour in a certain space, depending on the spatial resolution of the overall model. Examples of space-based approaches include models for occupant presence, space heating and cooling controls and ventilation rates for typical space occupancy types in building energy modelling standards. Person-based approaches model every single presence, activity and action. They are governed by the individual characteristics and behavioural patterns of each person-category (e.g., full time employed resident, part-time employed resident, unemployed resident).

The statistical approach, applied by many scholars (Guerra-Santin 2011; Chen et al. 2015; Mora et al. 2015; Yang et al. 2015; Guerra-Santin and Silvester 2016; Guerra-Santin et al. 2016; Ben and Steemers 2018) requires large samples and it embeds the risk to not adequately deal with the socio-technical factors (e.g. how householders use domestic appliances or how they react to changes in the dwelling as a result of energy performance measures) (Lopes et al. 2012), although the added value is that it can lead to results generally valid at a broader scale than the local one.

The engineering approach makes use of building energy simulation programs (e.g., EnergyPlus, DeST, ESP-r) to assess the impact of certain behaviours in building energy performance. Scholars agree that occupant behaviour is a major factor contributing to the gap between the theoretical and actual energy consumption in buildings. Due to the stochastic nature of human behaviour, to achieve better predictions of building energy performance, models of human-building interaction have increasingly been integrated into building energy simulation algorithms. Such approaches typically rely on mathematical equations representing the relationship between specifically exercised energy-related behaviours (i.e., opening windows, drawing blinds and shades, operating artificial lights, using electrical equipment) and some physical variables of the indoor and outdoor environment, specific to a particular building setting (D'Oca et al. 2018). Before developing a model to describe occupant behaviour, it is necessary to clarify the resolution for the spatial, temporal, and occupant dimensions (Yan et al. 2015). A single model is unlikely to be generic enough to cover all solutions at different scales.

Data patterns using statistical analysis procedures, data mining, and machine learning techniques have been widely analysed in recent research to automatically extract information on behaviour patterns from big data streams. In particular, analytical techniques for big data such as data mining (Yu et al. 2011; D'Oca and Hong 2015; Ren et al. 2015) have the capability to provide qualitative and quantitative information on diverse user profiles in a block of buildings, enabling the use of more realistic hourly schedules in building performance simulation programmes. Data mining techniques are not intended as a substitute to or contrast with direct stochastic modelling approaches (Hong et al. 2017), but as ways to gather information to overcome the shortcomings of more traditional techniques.

Moving the attention from the building to the urban scale, urban building energy models have been conceived as planning tools for the holistic optimization of buildings, urban design, and energy systems in neighbourhoods and districts. However, impacts of different occupant behaviour modelling approaches into the various purposes of urban building energy models are still largely unknown, and inappropriate choice of occupant behaviour model could result in oversized district energy systems, leading to over-investment and low operational efficiency (Happle et al. 2018).

1.2. Household energy behaviour in different regulatory levels: a policy framework

Policy-makers are currently facing the challenge to design and implement effective housing renovation strategies both for the public and the private housing stock, able to support not only the technical and physical renovation, but also a change of paradigm in energy consumption. The more the energy efficiency of buildings is, the greater is the impact of household behaviour (Andersen et al. 2009; Guerra-Santin and Itard 2010; De Meester et al. 2013; Santangelo et al. 2018), therefore, there is a growing belief that the implementation of energy efficient measures should better cope with household needs and the ability and willingness of occupants to undertake changes in their daily behaviours.

Policies and regulations at different territorial levels are struggling to encourage decision-makers to include information to users as a prerequisite to implement effective energy efficiency strategies and to lower energy consumption. The sub-sections below provide an overview of current policy instruments (e.g., policies, regulations, directives, planning tools) clustered according to the level of governance, to find out to what extent and how the three main topics (i.e., renovation of buildings, consumer behaviour and awareness, and public buildings/ social housing) are addressed.

1.2.1. Global level

At international level, in the last decade understanding the impact of the human factor in energy consumption got an increasing attention.

At organisational level, the Organisation for Economic Cooperation and Development (OECD) conducted a survey in 2011 to get an insight into the factors affecting people behaviour towards the environment and on what policy measures enable changes at the household level (OECD 2014). The International Energy Agency (IEA) identified occupant behaviour as one of the six driving factors of energy use in buildings (International Energy Agency 2016), and has developed the IEA EBC Annex 66: Definition and Simulation of Occupant Behavior in Buildings, aimed at analysing and evaluating the impact of occupant behaviour on building energy use and occupant comfort via building performance simulation (Yan and Hong 2018). The World Business Council for Sustainable Development recognised that occupant behaviour can have as much impact on energy consumption as the efficiency of equipment in reducing energy consumption (World Business Council for Sustainable Development 2007).

At policy level, there are several initiatives to further investigate. The Sustainable Development Goals (SDGs) are the set of 17 agreed goals which all 193 United Nations member states have committed to, that should guide policy and funding for the period 2016-2030. The SDGs build on results of the Millennium Development Goal of 2000 and they focus on key areas including poverty alleviation, democratic governance, climate change, disaster risk, and economic inequality. Among them, SDG7 and SDG11 focus respectively on Affordable and clean energy and Sustainable cities and communities. The former deals with ensuring access to affordable, reliable, sustainable and modern energy for all. Target 7.1 “by 2030, ensure universal access to affordable, reliable and modern energy services” is particularly relevant to the aim of this research, since it recognises the importance of household behaviour in energy consumption, and the need to investigate energy used differentially by household characteristics (i.e. gender), since it has different impacts on people well-being (UNSD 2016a). The latter is aimed at making cities and human settlements inclusive, safe, resilient and sustainable. Target 11.1 “by 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums” not only focuses on poor households and developing countries, but also to determine the structural quality/durability of dwellings in developed countries (UNSD 2016b).

The Paris Agreement (UN 2015), the first global agreement on climate change mitigation, has been adopted in 2016 under the United Nations Framework Convention on Climate Change, with the aim of keeping the increase in global average temperature to well below 2°C above pre-industrial levels, and strengthening societies’ ability to deal with the impacts of climate change. The agreement recognises the role of non-party stakeholders in addressing climate change, including cities, other subnational authorities, civil society, the private sector and others. In particular, in Article 12 it explicitly asks parties to cooperate in taking measures to enhance climate change education, training, public awareness, public participation and public access to information. More recently, in 2018 the 24th Conference of the Parties to the United Nations (UN) Framework Convention on Climate Change (COP24) resulted in the “Katowice decisions”, which constitute the rulebook for the Paris Agreement. They give an operational interpretation to the Agreement and top-down direction to complement the bottom-up approach of ‘nationally determined contributions’ (NDCs). However, current emission pledges to the Paris Agreement have already revealed insufficient to hold the global average temperature increase to well below 2°C above pre-industrial levels (among others: Peters et al. 2017; Karatayev et al. 2021).

The Habitat III New Urban Agenda (UN 2017) has recognized the role of sustainable consumption to ensure environmental sustainability (art. 14c) and the national, subnational and local governments as key actors to promote energy conservation and efficiency, and to develop sustainable, renewable and affordable energy and energy-efficient buildings (art. 75). Article 67 also stresses the importance of the promotion of well-connected networks to improve the resilience of cities to climate change, improving household quality, and promoting attractive and liveable cities.

Cities for Adequate Housing – Municipalist Declaration of Local Governments for the Right to Housing and the Right to the City – is the most recent initiative among the ones investigated (Cities for Adequate Housing 2018). It has been built on New Urban Agenda of Habitat III and SDGs of United Nations. It identifies five actions that local governments should undertake to ensure people actual access to adequate housing, understood by the United Nations as the one that has the correct affordability, legal security of tenure, habitability, availability of services, materials, facilities an infrastructure, accessibility, location and cultural adequacy. Among them, action 2 claims for more funds to improve the public housing stocks, to contribute to achieving cities where all people have equal access to affordable housing. To date, the agreement has been signed by fourteen cities worldwide and three metropolitan entities.

1.2.2. A focus on EU

At European Union level, the building sector is the largest single energy consumer (40% of the total energy consumption), with the residential sector accounting for more than the 27% of final energy consumption. The European Commission has recognised the importance of buildings performance towards climate change mitigation and has set regulations to help promoting the use of smart technologies in buildings and to accelerate buildings renovation. Currently, about 35% of the buildings are over 50 years old and almost 75% of the building stock is energy inefficient, while only 0.4-1.2% of the buildings are renovated each year, depending on the Country (less than 1% on average). This renovation rate is clearly not enough considering that half of the residential stock was built before 1970, prior to the introduction of the first thermal regulations. Therefore, the increase of the renovation rate of existing buildings has the potential to lead to significant energy savings and the residential sector is the one which offers the greatest potential. Improving the energy efficiency of buildings can also generate other economic, social and environmental benefits. Better performing buildings provide higher levels of comfort, wellbeing and health for their occupants.

The Energy Performance of Buildings Directive (EPBD) 2010/31/EU, entered into force in 2010, together with the Energy Efficiency Directive (EED) 2012/27/EU of 2012, are the two main reference directives for EU Member States towards the implementation of energy saving measures. For what concerns the renovation of existing building stock, Articles 4 and 7 of the EPBD requires respectively to set minimum energy performance requirements for both new and existing buildings, and to stick buildings undergoing major renovation into these requirements, while, coming to technology, Article 8 requires Member States to encourage the introduction of smart meters whenever a building is constructed or undergoes major renovation. Art 4 of the EED is devoted to building renovation, while Article 5 sets a binding renovation target for public buildings and imposes related obligations. It also stresses that governments shall undertake an exemplary role in the energy retrofit of the building stock in their countries. 3% of the total floor area of heated and/or cooled buildings owned and occupied by central government should be renovated each year to meet at least the minimum energy performance requirements that it has set in application of Article 4 of the EBPD. Member States shall encourage public administrations to follow the exemplary role of the central government, adapting energy efficiency plans, implementing energy management systems in their buildings, and making use of Energy Performance Contracting and services of Energy Service Companies (ESCos) (Art. 18). When it comes to the attention to consumers as a key component of the energy efficiency process, Article 20 of the EPBD requires Member States to take the necessary measures to inform the owners/tenants of buildings of the different methods and practices for enhancing energy performance. The EED as well makes the role of consumers explicit through Articles 9 (Metering), 10 (Billing information) and 12 (Consumer information and empowering programme), suggesting that raising awareness of the cost saving potential of building renovation can be achieved through judicious use of the regular communication channels (i.e. meters and energy bills) to bill payers, as well as through other ways of engaging with building owners and energy consumers. Article 7 of EED requires EU countries to set up an Energy Efficiency Obligation Scheme. This scheme requires energy companies to achieve yearly energy savings of 1.5% of annual sales to final consumers. In order to reach this target, companies need to carry out measures which help final consumers improve energy efficiency. This may include more physical measures as improving the heating system, installing double glazed windows, and better insulating roofs, or alternative policy measures which reduce final energy consumption, as training and education initiatives.

The Directive 2018/844/EU, amending the Energy Performance of Buildings Directive (EPBD) and Energy Efficiency Directive (EED), entered into force in July 2018, aims at accelerating the cost-effective renovation of existing buildings and promoting smart-ready systems and digital solutions in the built environment, therefore, providing consumers with more accurate information about their consumption patterns. This Directive is part of the Clean Energy for All Europeans, a new package of measures introduced in 2016 with the goal of providing the stable legislative framework needed to facilitate the clean energy transition and enabling the EU to deliver on its Paris Agreement commitments. Among the package three main goals, providing a fair deal for consumers is the one which is aimed at making easier for households and businesses to become more involved

Table 1.1. Overview of global and EU policy instruments addressing renovation of buildings, consumer behaviour and awareness, and public buildings / social housing

Name and year	Type	Renovation of buildings	Consumer behaviour and awareness	Public (residential) buildings
Global level of governance				
Sustainable Development Goals: SDG7 and SDG11 (2016)	Policy	SDG11 Target 11.1 “by 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums” to determine the structural quality/ durability of dwellings	SDG7 Target 7.1 “by 2030, ensure universal access to affordable, reliable and modern energy services” recognises the importance of household behaviour in energy consumption	n.a.
Paris Agreement (2015, into force in 2016)	Agreement	n.a.	Parties shall cooperate in taking measures, as appropriate, to enhance climate change education, training, public awareness, public participation and public access to information (art. 12)	n.a.
Habitat III New Urban Agenda (2016)	Policy	n.a.	Promotion of well-connected networks to improve the resilience of cities to climate change, improving household quality, and promoting attractive and liveable cities (art. 67)	National, subnational and local governments as key actors to promote energy conservation and efficiency, and to develop sustainable, renewable and affordable energy and energy-efficient buildings (art. 75)
Cities for adequate housing (2018)	Joint Declaration	Action 2 claims for more funds to improve the existing housing stocks	n.a.	Action 2 claims for more funds to improve the public housing stocks

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EU level of governance				
Energy Performance of Buildings Directive 2010/31/EU (EPBD) (2010)	Directive	Major renovations of existing buildings, regardless of their size, provide an opportunity to take cost-effective measures to enhance energy performance (art. 4 and 7)	Member States shall take the necessary measures to inform the owners or tenants of buildings or building units of the different methods and practices that serve to enhance energy performance (art 20)	The public sector in each Member State should lead the way in the field of energy performance of buildings, and, therefore, the national plans should set more ambitious targets for the buildings occupied by public authorities
Energy Efficiency Directive 2012/27/EU (EED) (2012)	Directive	Member States shall establish a long-term strategy for mobilising investment in the renovation of the national stock of residential and commercial buildings, both public and private (art. 4)	Member States shall take appropriate measures to promote and facilitate an efficient use of energy by small energy customers, including domestic customers (art. 12)	Exemplary role of public bodies' buildings. Buildings owned by public bodies account for a considerable share of the building stock and have high visibility in public life (art. 5)
Directive 2018/844/EU amending EPBD and EED (2018)	Directive	Art. 2a has been added to specify the long-term renovation strategy with a view to the long-term 2050 goal of reducing greenhouse gas emissions in the Union by 80-95 % compared to 1990, by specifying indicative milestones for 2030 and 2040	Smart-ready systems and digital solutions in the built environment offer new opportunities for energy savings, by providing consumers with more accurate information about their consumption patterns	Member States should provide clear guidelines and outline measurable, targeted actions as well as promote equal access to financing, for energy-poor consumers, for social housing and for households who are subjected to split-incentive dilemmas, also considering affordability

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COM(2016) 860 final Clean Energy For All Europeans (2016)	Strategy	n.a.	Among the package three main goal, providing a fair deal for consumers is the one which is aimed at making easier for households and businesses to become more involved in the energy system	n.a.
Strategic Energy Technology (SET) Plan (2017)	Strategy	n.a.	It claims for a smarter energy system, empowering the consumer	n.a.
European Green Deal (2019)	Strategy and Action Plan	To organise renovation efforts into larger blocks to benefit from better financing conditions and economies of scale. The Commission also works to lift national regulatory barriers that inhibit energy efficiency investments in rented and multi-ownership buildings.	n.a.	Particular attention should be paid to the renovation of social housing, to help households who struggle to pay their energy bills

in the energy system (i.e. by being entitled to generate electricity for either their own consumption, store it, share it, consume it or to sell it back to the market), to better control their energy consumption and respond to price signals. The shift from target group to actor, from consumers to prosumers requires to investigate behaviour at first, to being able to drive the change by addressing specific needs.
The Strategic Energy (SET) Plan, introduced in 2007 and integrated 10 years later in 2017, focus on preparation and endorsement of implementation plans which identify R&I activities and demonstration projects required to achieve the targets. It claims for a smarter energy system, empowering the consumers. However, in the pathway to define the measures to be implemented, it has lost the focus on the coordinated planning between the European level, Member States and the local level that some scholars identified in the earlier version of the SET Plan (Papa et al. 2016), and it is now more focused on sectoral innovations.
More recently, the European Green Deal launched at the very end of 2019 set out that improving energy efficiency in buildings has a key role to play in achieving the

ambitious goal of carbon-neutrality by 2050. With certain renovation measures targeting social housing, and new rules for EU countries to measure and monitor households vulnerable to energy poverty, the building renovation rules are conceived to ensure that no citizen is left behind in the clean energy transition.
The above-mentioned policy instruments are summarised in Table 1.1, where their provisions to address renovation of buildings, consumer behaviour and awareness, and public buildings/ social housing are briefly described.

1.2.3. A focus on Italy

National level

Member states have adopted a wide range of policy instruments to embed EU strategies for energy efficiency into national contexts. In the case of Italy, the Legislative Decree 102/2014, which transposes the EED, identifies requirements designed to ensure optimal coordination of interventions and measures for energy efficiency. The requirements aim at the full implementation of the commitments made at EU level in terms of improving energy efficiency, reducing consumption of the national housing stock, and promoting compliance with the mandatory redevelopment of central public administration buildings. In this regard, Article 5 of the decree provides incentives for the energy renovation of publicly owned property. Furthermore, the Legislative Decree 102/2014 foresees that by the end of 2016, multi-dwelling buildings install individual meters for each housing unit. Nevertheless, even if providing data on energy consumption and expenditures is a key factor to raise awareness of the role of occupant behaviour on implementing energy efficiency measures, the metering of energy consumption for each dwelling alone might not lead to responsible behaviours. Legislative Decree 102/2014 also indicates the National Agency for Energy and Environment (ENEA) as responsible for the elaboration of the long-term strategy for the renovation of the building stock.
The Italian energy efficiency action plan (PAEE) developed in 2014 (ENEA 2014) describes the energy efficiency targets set by Italy for 2020 and the measures to achieve them. To reach the goals, ENEA was expected to implement an Integrated Plan for energy efficiency dissemination (PIDEE) to provide information and training activities on energy efficiency, together with a definition of objectives and target groups. Although it has never been implemented as such, in the second version of PAEE, updated in 2017, a specific three-year information and training programme (PIF) has been developed. The programme is divided into three different stages, each lasting one year: Stage 1 (Start-up) involves mass information/communication to provide a basic introduction to energy efficiency and energy savings, and selected actions are planned for selected target groups; Stage 2 (Specific targets) is the midpoint of the programme, which involves maximising information coverage and launching targeted actions for the target groups identified under Article 13 of Legislative Decree No 102/2014. Objective 5 – Households is aimed at raising awareness among households, particularly in multi-dwelling buildings, of the benefits of energy audits, the energy performance certificate (EPC) and environmentally conscious energy

use. Stage 3 (Consolidation and testing) foresees the consolidation of initiatives, communication of results and analysis of the communication impact.
The Italian National Energy Strategy (SEN) 2017 lays down the actions to be achieved by 2030, in accordance with the long-term scenario drawn up in the EU Energy

Table 1.2. Overview of Italian policy instruments at national level addressing renovation of buildings, consumer behaviour and awareness, and public buildings / social housing

Name and year	Type	Renovation of buildings	Consumer behaviour and awareness	Public (residential) buildings
Legislative Decree 102/2014 (2014)	Regulation	Two instruments for building renovation: National buildings energy renovation strategy (STREPIN); Energy renovation plan for public administrations (PREPAC)	Prompting easy-to-read information on energy cost to consumers, allowing comparisons with average consumptions (art 9). Awareness raising to household, in particular those living in multi-family buildings, on the importance of energy diagnosis and sustainable consumption patterns (art 13)	Article 5 as a whole is devoted to energy efficiency of public buildings
Italy's National Energy Strategy (SEN) (2017)	Strategy	The establishment of a long-term renovation strategy for public and private buildings is foreseen. Revising, strengthening and confirming the tax deduction scheme for energy-efficiency investments (so-called "Ecobonus")	Low awareness of the impact of consumer behaviour is limiting the reduction of energy consumption. SEN aims at strengthening measures to support behaviour change and to build community awareness sharing the same energy reduction goal	Focus on energy efficiency for mitigating energy poverty, and on financial instrument to lead to the deep regeneration of public housing. Definition of the Energy renovation plan for public administrations (PREPAC) for the period 2021-2030

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Italian Energy Efficiency Action Plan (PAEE 2014 and 2017)	Action Plan	The establishment of a long-term renovation strategy for public and private buildings is foreseen, in agreement with art 4 of 2012/27/UE Directive	In PAEE 2014, the integrated plan for the dissemination of energy efficiency (PIDEE) is foreseen, but never implemented as such; in PAEE 2017, specific three-year information and training programme (PIF) is developed. It is divided into three different stages	In PAEE 2014, funds are reserved to the renovation of public housing; in PAEE 2017, public housing associations are also eligible for tax relief on expenditure incurred for renovation works carried out on public housing they own/manage
Italian National Energy and Climate Plan (PNIEC) (2020)	Action Plan	Energy renovation of buildings and neighbourhoods are encouraged to be undertaken together with the structural renovation, earthquake-proofing, systems upgrading and refurbishment thereof, in line with the strategy for energy renovation of the building stock by 2050. The tax deduction rate for some energy efficiency and anti-seismic interventions is raised up to 110% of the expenditure incurred (Superbonus)	Increasing digital connectivity (ultra-wideband technology) and the development of applications for remote control of buildings, in order to provide accurate and timely information to the consumer about their own energy consumption, a necessary condition for promoting efficient behaviour	It acknowledges the importance of renovation measures of social housing buildings to pursue various different objectives simultaneously, also reducing the burden of energy bills for the most vulnerable households. There is a clear link between renovation of social housing and alleviation of energy poverty

Roadmap 2050, which claims for a reduction of emissions by at least 80% from their 1990 levels. It aims to drive the national change towards a more competitive, more secure and more environmentally sustainable energy model. For the renovation of the residential sector, it foresees revising, strengthening and confirming the tax deduction scheme for energy-efficiency investments (so-called "Ecobonus"). Italian SEN recognises that low awareness of the impact of consumer behaviour is limiting the reduction of energy consumption. As a consequence, it aims at strengthening measures to support behaviour change and to build community awareness sharing the same energy reduction goal. For what concerns public buildings and social housing, it focuses on energy efficiency for mitigating energy poverty, and on financial instruments to lead to the deep regeneration of public housing.

More recently, the Italian National Energy and Climate Plan (PNIEC), developed at the very beginning of 2020, is the key policy instrument for changing Italian energy and environmental policy towards decarbonisation. The plan is structured in five lines of action, which are expected to be developed in an integrated manner: from decarbonisation to energy efficiency and security, passing through the development of the internal energy market, and research, innovation and competitiveness. Energy efficiency through renovation of residential buildings is largely considered among the ten specific objectives of the strategy, especially in the form of tax deduction up to 110% (i.e., Superbonus) for specific energy efficiency and anti-seismic interventions. On the contrary, the relevance of the human factor to optimise and decrease energy consumption is not fully acknowledged and translated in one or more specific strategies, although the plan states that to provide accurate and timely information to the consumer about their own energy consumption is a necessary condition for promoting efficient behaviour. The PNIEC makes a clear link between renovation of social housing and alleviation of energy poverty, as it recognises the importance of renovation measures of social housing buildings to pursue various different objectives simultaneously, also reducing the burden of energy bills for the most vulnerable households.

The above-mentioned policy instruments are summarised in Table 1.2, where their provisions to address renovation of buildings, consumer behaviour and awareness, and public buildings/ social housing are briefly described.

Regional level: Emilia-Romagna Region

The Italian Emilia-Romagna Region is considered for investigating the regional level of governance. The first Regional Energy Plan, approved according to the procedures established by Law no. 26/2004 on energy planning, was approved in November 2007 and designed to last ten years. The new Regional Energy Plan has been, therefore, released in 2017. Although the ten-years duration, to build regional scenarios coherent and comparable with the EU objectives, the horizon considered is the 2030. Two main scenarios have been identified and described: the "energy trend scenario" and the "energy goal scenario". The former takes into account the goals set by European, national and regional policies, the results achieved by the measures implemented and by the technological and market trends considered to be consolidated, without taking into account not yet foreseen interventions at any level of governance. The latter aims to achieve all the EU 2030 climate-energy objectives, including also the most challenging as the reduction of greenhouse gases (GHGs). This second scenario has been defined starting from the best national and European sectoral practices (Regione Emilia-Romagna 2017). In both scenarios, the residential sector is considered the key player to implement the strategies for increasing the energy performance

Table 1.3. Overview of the policy instruments for Emilia-Romagna Region addressing renovation of buildings, consumer behaviour and awareness, and public buildings / social housing

Name and year	Type	Renovation of buildings	Consumer behaviour and awareness	Public (residential) buildings
Emilia-Romana Regional Energy Plan (PER) (2017)	Strategy	The residential sector has the highest potential when it comes to increase energy building performance. Therefore, the Region promotes the renovation of the existing stock	Promotion of campaigns to raise awareness among consumers and of projects for increasing the adoption of energy efficient behaviour	Public administrations have a leading role in showcasing benefit of retrofitting the public building stock, in agreement with 2012/27/UE Directive
Emilia-Romana Regional Energy Plan – Action Plan for 2017-2019 (PTA 2017-2019)	Action Plan	Axis 4 as a whole is devoted to building renovation and urban regeneration	To raise awareness on the benefit of energy efficiency measures, specific actions targeted to multi-family building managers may be promoted (IV.2.4. Axis 4)	The region is committed to renovate its own public building stock to at least 3% as required for national government buildings. Energy efficiency initiatives for public housing can be supported
LR24/2017 Regional legislation on the territory protection and use (2016)	Regulation	To promote urban regeneration, to enhance the urban and built environment quality, healthy and energy efficient housing	n.a.	To promote affordable housing, new social housing buildings can be made through additional building floor for renovation and urban regeneration projects (art 8)

of the building stock. The "energy trend scenario" foresees a reduction of 2% of electricity consumption yearly, a double rate of dwellings undergoing renovation and energy retrofit – from 35% to 63% and from 9% to 22% respectively – and installation of smart meters in dwelling with decentralised heating system. The "energy goal scenario" aims at reducing 3% of electricity consumption yearly, to reach 89% of renovation rate and 30% of energy retrofit. The renovation of buildings is expected to be boosted by the definition of urban regeneration

regulatory system where the energy efficiency should be embedded. However, no more specific information is provided. When it comes to raise awareness among consumers on behaviour, and to public housing, the strategies are aligned with the ones at EU and national level, but no specific sub-strategies or actions to reach the overarching objectives are provided.
The Emilia-Romana Regional Energy Plan – Action Plan for 2017-2019 (PTA 2017-2019) is the responsible of driving the change for the first three-year period. Eight intervention axes are defined, whit the fourth one devoted to building renovation and urban regeneration. To raise awareness on the benefit of energy efficiency measures, specific actions targeted to multi-family building managers might be promoted (IV.2.4. Axis 4). The region is committed to renovate its own public building stock to at least 3% as required for national government buildings. In addition, the Action Plan foresees the support of the Region for energy efficiency initiatives for public housing.
Moving to understand how energy issue and the three main topics investigated in this section (i.e., renovation of buildings, consumer behaviour and awareness, and public buildings) are taken into consideration in the urban planning regional regulation, LR24/2017 Regional legislation on the territory protection has entered into force in 2018 to promote urban regeneration, to enhance the urban and built environment quality, healthy and energy efficient housing. Indeed, in Italy spatial planning is a regional legislative subject. To promote affordable housing, it foresees to promote new social housing buildings in case of energy renovation and urban regeneration projects through additional building floor area (art 8). Therefore, while renovation of buildings and enhancement of social housing as a common are stressed, no explicit reference is made to the role that people have in reducing energy consumption of buildings through their behaviour.
The above-mentioned policy instruments are summarised in Table 1.3, where their provisions to address renovation of buildings, consumer behaviour and awareness, and public buildings/ social housing are briefly described.

Local level: the City of Bologna

For several decades, the city of Bologna has undertaken a strategy for reducing CO_2 emissions and energy consumption by integrating energy policies within urban-scale strategies. This process began in 1982, with the Bologna Energy Study – BEST – on the city's energy consumption and continued with the project called UrbanCO2Reduction (1995), which paved the way to the definition of the first Municipal energy plan in 1999. Later on, in 2007, the Municipality of Bologna approved the municipal energy programme (Programma Energetico Comunale – PEC), aimed at defining the strategies to comply with the Kyoto protocol. Several Urban Energy Basins (Bacini Energetici Urbani – BEU) have been identified within the city to apply energy equalisation procedures between renovated and new buildings. Action factsheets are then designed to guide the interventions and to make distinctions between suggested and mandatory actions. The analytical phase includes a spatial dimension of energy

demand and supply, which represent an innovative feature compared to similar tools (Verones 2013). The programme is target to public (municipal) buildings, municipal vehicle fleet and public street lighting, and it suggests to involve private actors on a voluntary basis for what concerns the building renovation, while it imposes energy performance requirements to be embedded in the building regulation and planning tools. The close integration between PEC, the structural planning tool and the methodology for the definition of the urban energy basins has been considered as a valuable example in the Italian national scene (Conticelli et al. 2017). However, as the majority of the policy instruments, all the considerations on energy savings are based on the reduction of the energy demand, rather than the reduction of energy consumption. Therefore, no considerations are made on consumer behaviour and awareness.
In 2008 Bologna joint the Covenant of Mayors, the main EU initiative promoting the involvement of local authorities in addressing climate change related issues. The key instrument is the elaboration of a Sustainable Energy Action Plan (PAES) and the monitoring process to verify how the measures adopted contribute to achieve the targets. Bologna PAES, approved in 2012, identifies a series of actions, clustered in fact sheets, according to six macro areas of intervention: residential sector, tertiary sector, industry, local energy production, urban mobility and public facilities. The public housing stock is considered to have a leading role in showcasing the energy saving potential of the residential sector. With about 12,000 dwellings, is the largest housing stock owned by a single entity (the Municipality of Bologna itself), therefore, each energy efficiency action has a high replication potential. Among the actions proposed addressing somehow consumer behaviour, the "Energy Point" (Il Punto Energia) is a public spot that provides information to citizens (both households and SMEs) on cost-effective measures for renovating buildings and for increasing energy efficiency of both housing and working places, while "What can you do?" (Cosa puoi fare tu?) is a web platform providing information to energy efficiency measures for building renovation. Other actions are particularly targeted to public buildings, either to renovate the public housing stock and other public buildings, or to support the urban regeneration of brownfields and former barracks increasing the energy efficiency of new buildings and energy infrastructures. Specific urban planning tools are foreseen to implement some of the actions with an urban planning scope (Proli et al. 2016). However, results are largely disregarded, due to the non-binding nature of the proposed actions, the construction sector stagnation as a consequence of the 2008 economic crisis, and the lack of public funds to be invested in the energy renovation of public buildings. However, two main limitations are embedded in the two plans: on the one hand, they devoted their attention mainly to new urban developments and green fields, rather than to existing built-up areas; on the other hand, the intention to integrate urban and energy planning resulted disattended.
In 2021, the Municipality of Bologna has released and adopted the new version of the action plan – the Sustainable Energy and Climate Action Plan (PAESC) –

as required by the Covenant of Mayor, addressing both climate mitigation and adaptation with a 2030 horizon. The PAESC describes specific set of measures according to macro-area of interest, consisting of a set of interventions whose implementation will contribute to the achievement of the mitigation and adaptation objectives identified for that area. The monitoring procedures and related indicators are also reported for each area of action. Although some limitations identified for the PAES are still present and valid also for PAESC – non binding nature of the plan and the actions it contains, and not perfect integration with the urban planning tools – the new document successfully moves the attention from new urban developments to the regeneration of the existing city. The objectives of the plan are both mitigation (i.e., reduction of CO2 emissions by 40% in 2030 compared to emissions in 2005) and adaptation. While the renovation of the public housing stock is identified as one of the key actions, and renovation of residential buildings is largely included within the actions, the actions to raise awareness and lead to behaviour change seem insufficient and not integrated with the hard and technological measures.

To the aim of this analysis, the urban planning tools are considered as well, since they are the policy instruments responsible to translate the building strategies into actions at local level. At the time this research has been performed, the Municipality is facing a transition phase of paramount importance when it comes to the urban planning tools. According to the latest Regional Legislation on territorial protection and use (i.e., LR24/2017), all the municipalities in the Emilia-Romagna Region must adopt a new urban planning tool - the General Urban Plan (Piano Urbanistico Generale – PUG) – that varies greatly from the previous tools. Being the process still ongoing for more that 90% of the municipalities in the region, to the aim of this research, the characteristics of both new and previous planning tools are taken into account and described, providing an exhaustive framework of the urban planning tools that have followed in the last 10 to 15 years.

The Municipal Structural Plan (Piano Strutturale Comunale – PSC), approved in 2008, is responsible to define the strategy and structural characteristics of the urban planning process. The Environmental and Territorial Sustainability Assessment (Valutazione di Sostenibilità Ambientale e Territoriale – VALSAT), approved in 2008, is a mandatory step of the planning process aimed at assessing the effects of the PSC actions to guarantee the sustainability of transformations, both at the micro-scale and at the city scale of intervention. When it comes to the integration of energy-related issues into urban planning tools, VALSAT should work as a bridge between the Municipal Energy Programme and the Municipal Structural Plan, aiming at implementing main objectives of sectoral plans.

According to the former Emilia-Romagna Region law on urban planning (regional law n. 20/2000 – overcomed by the LR24/2017), the Municipal Structural Plan strategies and objectives are put in practice though the Urban Building Regulations (Regolamento Urbanistico Edilizio – RUE), establishing rules and procedures about how to intervene on buildings and the Municipal Operative Plan (Piano Operativo Comunale – POC), addressing the major urban transformations to be implemented though detailed masterplan of the affected city areas.

Bologna RUE, approved in 2009, aims, by means of volumetric incentives, at improving the sustainability of building changes and the energy efficiency of the existing city. The RUE adopts a performance-based approach strongly founded on sustainability performances. It is grounded on a reward-based mechanism under the form of density bonus incentives to be granted in case of demolition and reconstruction as well as of global renovation of existing buildings, in case these interventions achieve higher performances against four main requisites, where one of them considers the energy efficiency of buildings.

The Municipality of Bologna has approved in 2015 a POC explicitly dedicated to a widespread qualification of some underused od degraded part of the cities, taking the benefits of public-private partnerships to provide energy efficiency retrofitting programmes in the wider framework of urban sustainability and regeneration. By a formal expression of interest, owners of underused or abandoned buildings and small-scale developers have been able to propose improvements, re-functioning, enlargements of existing buildings to be included within POC. In order to be accepted by the Municipality and included in the POC, the proposals had to achieve the main objectives described in POC public announcement: improvements in terms of energy efficiency, seismic performance, natural resources management, and improvements of urban and social quality improving local public spaces and facilities and providing social housing. As a reward, proponents can count on additional building rights to be exploited within the belonging plot or in other plots to be agreed with the Municipality. The experience of Bologna POC shows an alternative way of planning small-scale interventions on the built environment, based on bottom-up proposals designed by small owners and local operators according with their aims and possibilities, but in line with the overall sustainability framework fixed by the municipal urban plan (Conticelli et al. 2017).

Starting from 2008, the Municipality of Bologna has raised its awareness about the problems of the existing city and this attention have been evident and more explicit since 2011, when the city has started redefining its municipal urban planning strategies by adopting a new approach more focused on the management and improvement of existing buildings and already built environment in terms of environmental and social benefits, rather than new urban developments (Conticelli et al. 2017). Therefore, the urban planning instruments presented above reflect this change. However, to the aim of this investigation, neither the RUE, nor the POC take into consideration the leading role the public authorities should have to implement the energy renovation strategies in their public building stock. No measures are foreseen to support the raise of awareness among citizens on the impact of their behaviour.

To this aim, the LR24/2017 Emilia-Romagna Regional legislation on the territory protection and use, entered into force in 2018, seems to provide new opportunities. As explained above, besides no explicit reference is made to the role that people have in reducing energy consumption of buildings through their behaviour, the legislation is much more focused on home-owners and individuals as activators of urban regeneration process than the former spatial planning regulations. Indeed, due to the Italian housing stock tenure, totally unbalanced in favour of ownership, the involvement of individuals is a fundamental step to unlock the city regenerative potential.

Bologna has adopted the new General Urban Plan (PUG) in 2021, definitively moving from the idea of a prescriptive plan in favour of a strategic planning tool. Three stand-alone documents (i.e., PSC, RUE and POC as described above) have been replaced by one planning tool only, which includes the key elements to govern the city transformations. One of the three main strategies focuses on "Resilience and the environment" and it supports energy transition through the retrofit of the existing buildings. Within the Building Regulation (RE), expected energy performances of retrofitted buildings are described. Consumer behaviour and awareness are not mentioned throughout the PUG, and the impact of households to effectively reduce the energy consumption after energy retrofit is neglected. On the contrary, affordable housing is the core of the second strategy called "Housing and inclusion". The demand of new social housing stock is quantified in 6,000 units, that should be built in the next 10 years. Urban areas that will host new social housing buildings have been identified. In case of large urban transformations from private developers, up to 30% of the volume for housing should be for social housing, thus involving private resources in building a public common good as social housing.

The above-mentioned policy instruments are summarised in Table 1.4 where their provisions to address renovation of buildings, consumer behaviour and awareness, and public buildings/ social housing are briefly described.

Table 1.4. Overview of the policy instruments for the City of Bologna addressing renovation of buildings, consumer behaviour and awareness, and public buildings/ social housing (Source: author's elaboration)

Name and year	Type	Renovation of buildings	Consumer behaviour and awareness	Public (residential) buildings
Municipal energy programme (PEC) (2007)	Strategy/ Action Plan	Several "energy urban basins" (BEU) have been identified within the city to apply energy equalisation procedures between renovated and new building complexes	n.a.	Actions within the "energy urban basins" reported in the atlas are targeted to public buildings
Bologna Sustainable Energy Action Plan (PAES) (2012)	Action Plan	Building renovation is a practice embedded throughout the Action Plan	"The Energy Point" is a public spot that provides information to citizens (both households and SMEs) on cost-effective measures to renovating buildings and to increase energy efficiency of both housing and working places	Actions targeted to public buildings, either to renovate the public housing stock and other public buildings, or to support the urban regeneration of brownfields and former barracks are foreseen
Bologna Sustainable Energy and Climate Action Plan (PAESC) (2021)	Action Plan	Building renovation is a practice embedded throughout the Action Plan	While the importance of raising awareness of households and citizens is acknowledged, actions are vague and weak, mostly related to a change of cultural paradigm for energy transition, and not specifically related to provide guidance to households to optimise their energy behaviour	The renovation of the public housing stock is identified as one of the key actions

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Municipal Structural Plan (PSC) (2008)	Planning tool	The energy issue is addressed through a set of building performance standards, promotion of building retrofit and renewable energy sources	n.a.	It is recognised the key role of maintenance and management of the public housing, particularly in those districts where it is concentrated
Urban Building Regulations (RUE) (2009)	Building regulation	Building renovation focuses on the retrofit of building envelopes and energy infrastructures. Reward-based mechanism under the form of density bonus incentives	n.a.	n.a.
Municipal Operative Plan (POC) (2015)	Planning tool	Public-private partnerships to provide energy efficiency retrofitting programmes	n.a.	The provision of social housing is among the criteria to comply with in order to implement urban transformations
General Urban Plan (PUG) (2021)	Planning tool (Strategy)	One of the three main strategies focuses on “Resilience and the environment” and it supports energy transition through the retrofit of the existing buildings. Within the Building Regulation (RE), expected energy performances of retrofitted buildings are described.	n.a.	Affordable housing is the core of the second strategy called “Housing and inclusion”. Urban areas that will host new social housing buildings have been identified. In case of large urban transformations, up to 30% of the volume for housing should be for social housing

1.3. Energy renovation and consumer behaviour in buildings: is there a role for urban planning and urban regeneration?

Energy efficiency has been recognised as a multiscale issue, addressed by several policies and regulations. It concerns all the levels of governance and it involves multiple stakeholders. However, as clearly framed in the previous section, and already investigated by other scholars (Papa et al. 2016; Conticelli et al. 2017; La Greca 2017), there is a general tendency both in legislation and strategies to focus on the building scale, rather than the urban scale. At the same time, urban planning is still not much driven by energy planning, which in turn does not pay enough attention to the territorial level (La Greca 2017).
The challenges imposed by climate-change and energy issues are very complex and need to be addressed from the global to the local scale. As a result, at all levels of governance, policy-makers are promoting integrated and adaptive strategies aimed at reducing or mitigating negative effects of climate change while reducing energy consumption and CO_2 emission.
Policy documents at the EU strategic level in the field of mitigation are primarily focus on the role that smart energy infrastructure, energy efficiency, renewable-energy projects, research and the deployment of new energy technologies may have in the reduction of energy consumption and CO_2 emission. While it is widely acknowledged in these documents that significant interventions are needed in the building sectors, there is no reference to the impact of spatial organization and physical planning on building consumption and associated GHG emissions in the EU (Papa et al. 2016).
Spatial planning is either a national or a regional legislation subject, depending on the Member States administrative characteristics and regulation, therefore, it is not surprising that is barely mentioned in international strategies and EU energy directives, with exception for the Habitat III New Urban Agenda. However, investigating the policy instruments at the Italian national level, the absence of measures and actions related to the design and use of territory is surprising and it is identified as a weakness element (Papa et al. 2016). Although the Italian national policy instruments have recognised the key role of building sector in changing the paradigms of energy demand and consumption, they identify either tax and financial measures or technological solutions as tools worth to be implemented, without any reference to the impact that spatial planning may determine.
On the one hand, similarly to what already identified by Papa et al. (2016), by considering the energy policy instruments it emerges that in none of the levels of governance investigated above spatial planning is truly implemented. Even at the local level (i.e. in both PEC and PAES/PAESC), where implementation should be at its most practical, measures are usually uncoordinated singular interventions grouped in factsheets, rather than according spatial planning objectives. On the other hand, the urban planning tools (e.g. PUG) at local level are still not enough driven by energy planning. The energy issue is always embedded in terms of performance and reduction of energy demand in buildings, while the role of building occupants in achieving such goals and the relationships between

behaviour and building characteristics (see Chapter 2) are completely neglected. Energy efficiency is considered to be a technology-driven issue, rather than a matter of behaviour and consumption patterns.

To the aim of this investigation, building energy renovation is believed to be a key opportunity to roll-out a comprehensive urban regeneration strategy with the aim of tackling energy poverty, boosting social cohesion and triggering local jobs. The active involvement of private actors and the citizens' empowerment is expected to boost the effectiveness of the urban regeneration actions, where the local authorities hold the role of public directors (Privitera 2017). Among the key ingredients of the regeneration process, there are: a strong long-term commitment from the public authorities; combination of social and physical measures; and involvement and empowerment of the people, who need to be much more aware of their role in lowering energy consumption in buildings.

As far as urban regeneration is concerned, the level of complexity is higher than for new development areas, consequently spatial planning should look for additional tools. Traditional analytical techniques, popular among spatial planners, have to be updated by using algorithms, models and data commonly used by computational social science. By using these technologies, new insights in the knowledge of urban structure and functions can be obtained. This updated level of knowledge is fundamental for fine-tuning the planning tools already described (Greca and Martinico 2016).

The urban scale is the most suitable level where all different renewal-oriented tools could be applied together, and the positive effects of incentives and rewards mechanisms could be multiplied. This would also allow the implementation of new and more collaborative approaches involving the public sector, occupants, households and developers acting in the building sector, driving the transition towards a credible and long-lasting model of low-carbon city (Conticelli et al. 2017). The energy efficiency process, to be effective in achieving energy reduction targets, should be conceived as a part of an integrated and broader urban strategy fostering urban regeneration of the existing city, where the local authorities have a key strategic role in coordinating and influencing the activities of a range of actors, in defining areas and communities to focus on, and in engaging people in changing behaviours in order to reduce energy consumption (Theobald and Shaw 2014). Therefore, investigating consumer behaviour in the framework of urban planning can provide an insight into the urban regenerative potential of cities, which relies – among others – on the one hand, on energy awareness of people, their behaviour, capacity and willingness to adapt, on the other hand, on the ability of public authorities to design renovation strategies to turn occupants into active actors, rather than passive target groups.

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››› 2.
Existing knowledge on household behaviour determinants and strategies to promote behavioural change

Evidence from research shows that the design of energy efficient buildings does not necessarily result in low energy buildings (Guerra-Santin and Itard 2010; Stevenson and Leaman 2010). The gap between expected and actual energy consumption in buildings is highly dependent from the human factor. Energy efficiency is not merely a matter of technology, but it depends on the use people make of it (Janda 2009; Paauw et al. 2009; Gram-Hanssen 2010; Gupta and Chandiwala 2010; Feng et al. 2016; Maghsoudi Nia et al. 2022). Even in high-energy performance homes, are still the households who ultimately determine the energy consumption. The more the energy efficiency of the buildings is, the greater is the impact of households (Andersen et al. 2009; Guerra-Santin and Itard 2010). For instance, according to Huebner et al. (2013), the use of a programmable thermostat can significantly decrease the energy consumed both for heating and cooling, with savings up to 30% for heating systems and 23% for cooling systems through setting night- and day-time setback temperatures, but such savings are not necessarily realised unless the user knows the thermostat control mechanism. Furthermore, research has shown that occupants can use three or more times as much energy for heating as their neighbours living in dwellings with similar characteristics (Steemers and Yun 2009; Gram-Hanssen 2010). The main factors that explain this performance gap and that have been investigated in recent years are the rebound effect (Haas et al. 1998; Barbu et al. 2013; Guerra-Santin 2013; Visscher et al. 2016), the prebound effect (Sunikka-Blank and Galvin 2012; Visscher et al. 2016), the occupant interaction with the building component (Schipper 1989), and the uncertainty of building performance simulation results, associated with uncertain occupant behaviour model inputs (Yan et al. 2015; Hong et al. 2015). The rebound effect occurs when households increase their consumption as a consequence of paying less attention to their energy-related behaviour, since they believe that the increase of energy efficiency in buildings should automatically be translated into a decrease of consumption, no matter the level of usage and their behaviour. According to the UK Energy Research Centre, it could offset 10–30% of energy savings (Elsharkawy and Rutherford 2015). On the contrary, the prebound effect has been formulated to explain the lower-than-expected energy use in old inefficient dwellings due to a lower comfort level accepted by the occupants. These factors should be considered as potential risks for the success of policy instruments for the reduction of household energy consumption. Moreover, when it comes to strategies and policies to drive the behaviour change towards lowering energy consumption, other risks may occur and reduce the effect of behaviour change strategies: the drawback effect is observed when people fall back on old habits

after the newness of the experiment wears out, while the Hawthorne effect occurs where achievements may be considered as a temporary result of occupants aware of being observed (Barbu et al. 2013). Hence, user behaviour in relation to energy efficiency in buildings is an emerging research topic which requires the integration of different and complementary expertise.
The aim of the chapter is to investigate the determinants of occupant behaviour and energy consumption, in order to understand, on the one hand the characteristics responsible of certain behaviour patterns, on the other hand the key success factors that should be embedded in the strategies to promote pro-environmental behaviour. The analysis and considerations that follow are the results of a desk research approach with a wide literature review.
Firstly, the determinants of energy behaviour in residential sector are investigated, on the one hand through a literature review of household and building characteristics affecting behaviour, on the other hand through a literature review of household behavioural patterns. Secondly, factors and strategies to promote efficient behaviours are presented, in particular focusing on the benefits and limits of the feedback approach. Moreover, the non-energy co-benefits of working through community-based initiatives instead of only retrofitting the buildings are illustrated as a possible way for moving from behaviour change to systemic change, and suggestions to properly design community behaviour change initiatives are provided. Finally, future challenges and policy implications are discussed.

2.1. Determinants of energy behaviour in residential sector

Available literature both from social and technical fields have investigated the determinants for explaining user behaviour and to identify consumption patterns. While the social science usually adopts both qualitative and quantitative methods to perform its studies, the scholars preferring a technological approach use extensively quantitative methods. They consist mainly of data collection through surveys and interviews (Andersen et al. 2009; Gram-Hanssen 2010; Huebner et al. 2013; Engvall et al. 2014; OECD 2014; Bal et al. 2021), reading from smart meters (Grønhøj and Thøgersen 2011; D'Oca et al. 2014a) and statistics (Schaffrin and Reibling 2015; Guerra-Santin and Silvester 2016), used individually or combined one to the others.
The research instruments mostly applied rely on theoretical framework and behavioural models (Van Raaij and Verhallen 1983b; Abrahamse et al. 2005; Stephenson et al. 2010) in the field of social science, and mostly on simulation tools (D'Oca et al. 2014b; Yan et al. 2015) and statistical analysis and data mining techniques (Steemers and Yun 2009; Ren et al. 2015) for the engineering science.

2.1.1. A literature review of determinants of household energy behaviour

Occupant behaviour is believed to be influenced by household characteristics, lifestyle, and cognitive variables (i.e. motivation, values and attitudes), but also buildings characteristics, which affect the interaction between the user and the building components and appliances.

Household characteristics

When it comes to household characteristics (i.e. demographic, educational and socio-economic), some links with user behaviour have been identified in the literature.

Based on self-reported behaviour of 145 households in the Netherlands for one year, Van Raaij and Verhallen (1983b) argued that life-style influences energy-related attitudes and behaviour. Family size and composition next to the presence or absence from home for work or leisure all have a direct effect on energy behaviour and energy use. Income, educational level, and employment showed also to be related to energy use. Two decades later, Poortinga et al. (2003) discovered differences in acceptability of energy-saving measures related to age, household type, income and education level.

Some among the influencing factors are strongly linked with the local/regional/national conditions (Guerra-Santin and Silvester 2016). Income is one of the most controversial among these factors. On the one hand, income has been shown to be a determinant of energy consumption in Mexico due to the inadequate thermal insulation of the buildings where low-income households mostly live (Romero et al. 2013). On the other hand, a study performed in the Netherlands showed no relationship between income and energy consumption (Guerra-Santin et al. 2009). Income is also one of the factors determining the prebound effect (i.e., the lower than expected energy use in old inefficient dwellings due to a lower comfort level accepted by the occupants). While high-income households have higher overall energy consumption, low-income groups spend a larger share of their income on utility costs (Schaffrin and Reibling 2015).

Some studies have shown that ownership has a positive influence on energy savings (Andersen et al. 2009; Martinsson et al. 2011; Guerra-Santin and Silvester 2016), while gender has also turned to be a significant determinant, with women more environmentally conscious than men (Carlsson-Kanyama and Lindén 2007; OECD 2014) and the proportion of women in the house giving a reduction in energy use for heating, assuming all other factors being equal (Engvall et al. 2014). The heating patterns vary depending on the age of households (Lindén et al. 2006) and employment status (Guerra-Santin and Silvester 2016), with older and retired people staying at home during daytime hours, therefore, with the heating system turned on for longer than other family groups. Brundrett (1977) showed that the number of open windows was higher in families where housewives stayed at home and that it increased with the size of the family.

The relation between occupant behaviour and health has been proved to be bilateral (Bedir 2017). Either the former affects the latter or the other way around. Indeed, household size and poor ventilation, volume of the dwelling and the heating system can have significant impact on NO_2 concentration, resulting in health problems like respiratory symptoms and reduced lung function (Cibella et al. 2015).

Education has been found to be insignificant in explaining energy consumption (Guerra-Santin 2010; Sapci and Considine 2014), while a higher education level

might be related to fewer hours of the heating system at the highest chosen temperature setting and lower education and presence of elderly are all related to more hours on the use of radiators and thermostats (Guerra-Santin 2010). Schweiker and Shukuya (2009) indicated that the use of air-conditioning units differed depending on the origin of a person, experience from childhood and attitude towards air-conditioning.
Motivation is another important determinant of electricity consumption (Lindén et al. 2006; Vringer et al. 2007). The perception of the environment and other factors concerning the dwelling can also impact the window opening behaviour (Andersen et al. 2009). Motivation and perception could be influenced through information, feedback and other educational and economic measures. Feedback in particular has proven to have a strong influence on occupant behaviour. As environmental concerns increase, households take direct action to conserve energy (Sapci and Considine 2014)

Building characteristics
The impact of the building thermal characteristics on space heating demand, as well as the one of efficiency of existing heating, ventilation and air conditioning (HVAC) systems and electrical appliances on electrical consumption have been studied and quantified for years, and they are basic knowledge for technical innovations and building energy performance simulations. However, the interest in building characteristics in relation to occupant behaviour has started to grow in the last decade (D'Oca et al. 2018). Building characteristics can be explained by external factors as the site and climate characteristics where the dwelling is located (e.g. outdoor air temperature, wind velocity and direction, horizontal global irradiance, air pollution and noise) and internal factors (e.g. building envelope and type of windows, dwelling size, mechanical systems and appliances). Guerra-Santin and Itard (2010) found that the main building characteristic determining behaviour is the type of temperature control, since households with a programmable thermostat were more likely to keep the radiators turned on for more hours than households with a manual thermostat or manual valves on radiators. Shipworth et al. (2010) found that households with thermostats set the mean temperature slightly lower than those without thermostat.
Hansen et al. (2018) found that practices of adjusting thermostats and the amount of clothing occupants wear indoors, as well as perceived indoor temperature, all correlate with building characteristics (e.g. energy efficiency of the building envelope and technical installations). These correlations are moderated by the socio-demographic characteristics of occupants. The results indicate that occupants dress warmer and keep lower temperatures in energy-inefficient dwellings.
One parameter having a high influence both on the energy consumption and on indoor environmental quality is the air change rate. Since the thermal load for ventilation is related to the air change rate, a close examination of this indicator is important to consider when investigating the effects of the occupant behaviour.

Natural ventilation is closely related to the heating consumption, and it is one of the main concerns for designers struggling with building energy performance. In order to reduce energy consumption, ventilation rate should be reduced as much as possible. Nevertheless, indoor air quality relies on a certain level of ventilation rate. Behaviour is also related with the type of ventilation system (i.e. natural or mechanical). According to Fabi et al. (2012) consensus has not been reached about whether to use indoor temperature, outdoor temperature or both as the independent variable when simulating window use, because of the inherent interactions between indoor and outdoor temperature in naturally-ventilated buildings. For instance, rising indoor temperatures might drive the opening of windows, but how long the window stays open might depend more on outdoor temperature.

When it comes to the electrical equipment, the introduction of energy labels has produced a positive trend in the sales of more energy efficient appliances. Consumers have responded positively to this mandatory information scheme enabling comparison of energy-efficiency of various appliance models through the ranking into the proper energy class (A–G) (D'Oca et al. 2014a). The number of home appliances and lighting appliances is believed to be a crucial factor in electricity consumption (Bedir 2017). Lighting varies according to the characteristics of the dwelling and the activities performed inside it.

2.1.2. A literature review of household behavioural patterns

Several scholars have categorized consumers and their energy and environmental attitudes to different behaviour patterns. Starting from the 1980s, Van Raaij and Verhallen (1983a) focused on the definition of five energy-related behavioural patterns (i.e., conservers, spenders, cool, warm, average) and verified that the average difference between the two extreme usage levels accounted for 31%.

The large survey conducted in 2011 by the Organisation for Economic Cooperation and Development on people's behaviour towards the environment (OECD 2014) has identified three clusters of environmental attitudes labelled environmentally motivated, environmental sceptics, and technological optimists. The environmentally motivated comprise just under half of the pooled sample and gather together people who believe that environmental problems are real and express a willingness to make compromises in their lifestyle to solve them, with the least need for reciprocation from others. Environmental sceptics believe that environmental issues are overstated and do not wish to pay for government environmental policies, although they do report a general willingness to make compromises for the benefit of the environment. Technological optimists share the belief with the environmentally motivated cluster that environmental problems are real and appear willing to make lifestyles compromises to solve them, but they show a greater belief in the potential of technological progress to solve environmental problems.

Abreu et al. (2012) adopted a pattern recognition method to identify user profiles of electricity consumption. The study explained that approximately 80% of

household electricity use results from the persistent daily routines and patterns of consumption or baselines, typical of specific weather and daily conditions. The applicable profiles for this population were unoccupied baseline, hot working days, temperate working days, cold working days, and cold weekend days.
By investigating the effect of thermostat and window opening behaviours, D'Oca et al. (2014b) grouped residential occupants into active, medium and passive energy users. While the active users change the heating set point to get warmer or cooler, the passive ones do not and better tolerate some level of discomfort.
Paauw et al. (2009) contributed to the research by setting the framework for the definition of an Energy Pattern Generation. They worked with five groups of households in the Netherlands, studied on the basis of household composition. Four profiles were built by relating energy consumption to income, environmental concern and personal comfort: convenience/ease profile, based on comfort assessed as important, but no interest in saving energy, money or the environment; conscious profile, with comfort as important, and some environmental and cost awareness; costs profile, where energy costs and saving money are the most important issue; and climate/environment profile, where environment is the most important value.
More recently, Guerra-Santin (2011) has conducted a research to statistically determine behavioural patterns associated with the heating consumption and to identify household and building characteristics contributing to the development of energy-user profiles. While the results have shown clear relationships between occupant behaviour and household characteristics, it was difficult to establish relationships among energy consumption and behavioural patterns and household groups.
Linden et al. (2006) provided an insight into behavioural patterns in Sweden and gave a bottom-up perspective on the policy instruments for driving the behavioural change, revealing behavioural patterns that are already efficient and those that need improvements, and the role of policy instruments to support the shift to efficient behaviours.
Gram-Hanssen (2010) applied the practice-theory approach on a study focused on how users regulate their indoor climate, and proposed a framework for understanding why they act as they do.
Hendrickson and Wittman (2010) developed a post-occupancy assessment (POA) tool for identifying several different occupant household consumption patterns.
Karatas et al. (2016) proposed a conceptual framework for selecting occupancy-focused energy interventions in buildings. This framework adopts a motivation, opportunity and ability (MOA) approach from the consumer and social marketing fields and foresees: measuring occupants pre- and post- intervention exposure MOA level and energy-use profiles; clustering occupants based on identified characteristics; choose energy-efficiency intervention strategies accordingly.
Energy Cultures (Stephenson et al. 2010; Barton et al. 2013), a research project aimed to help inform policy making related to residential energy use and energy efficiency in New Zealand, has clustered the energy consumers in four groups:

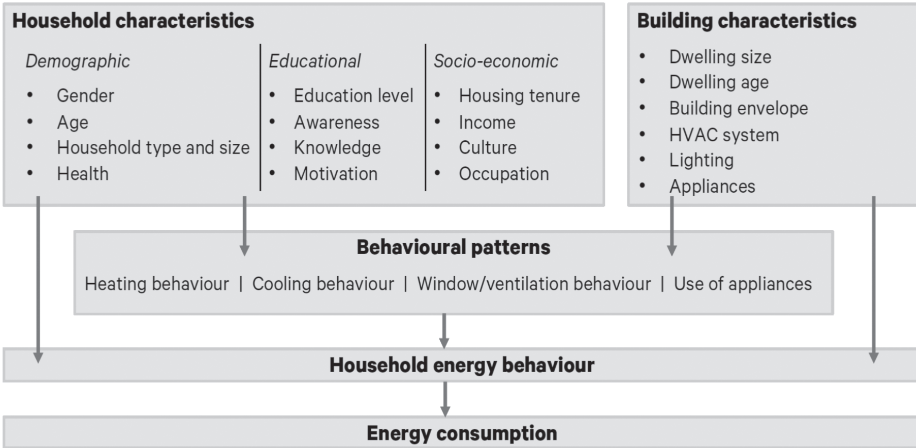

Figure 2.1. Framework for household energy behaviour and consumption (interpreted from literature review). Source: author's elaboration.

energy economic; energy extravagant; energy efficient and energy easy. According to the project results, the lowest energy users tend to have substandard housing and inefficient energy technologies, yet have very economical energy practices. This combination of circumstances tends to be aligned with cold, and often damp, housing. This cluster of households (around 25% of the population) has lower incomes and restricted choices, creating a substantial barrier to improving their energy situation. Households with the highest energy use tend to be those that pay little attention to improving the energy efficiency of their house, own many energy-using appliances, and have little regard to energy-efficient practices. This cluster of households (around 20% of the population) is generally wealthier and thus has fewer barriers than others to making efficiency improvements. This group represents a policy opportunity to achieve significant gains in energy efficiency and conservation.

Household characteristics, building characteristics, and behavioural patterns are summarised in Figure 2.1.

Household behaviour can be influenced by: demographic factors as gender, age, household type and size, health; educational factors as level of education, awareness, knowledge, motivation; socio-economic factors as housing tenure, income, cultural background, occupation.

Building characteristics considered are external factor such as outdoor air temperature, wind velocity and direction, horizontal global irradiance, air pollution and noise, and internal factors such as building envelope and type of windows, dwelling size, mechanical systems and appliances.

Both household and building characteristics are determinants of household behaviour and can explain household behavioural patterns. Many scholars have attempted to identify behavioural patterns able to explain and predict behaviour. To the aim of this research, the patterns have been grouped according to the type of energy end-use: on the one hand heating behaviour and window/ventilation behaviour affecting the heating consumption, on the other hand use of appliances and cooling behaviour contributing to electricity consumption. The definition of further and more detailed user patterns is beyond the scope of this research. Behavioural patterns cannot be defined by literature review since they are closely related to the household and building characteristics of the sample studied.

2.2. Strategies and tools to promote behavioural change

A number of studies have investigated the factors influencing household energy use and conservation.

Technological developments, economic growth, demographic factors, institutional factors and cultural developments are the five general macro-level factors (known as TEDIC factors) that form the societal context that inevitably influences individual behaviour (Abrahamse et al. 2005). In turn, these TEDIC factors shape micro-level factors such as motivational factors (e.g. preferences, attitudes), abilities and opportunities which form the MOA model (Steg 2008; Karatas et al. 2016).

According to Steg (2008) "firstly, individuals need to be aware of the need for and possible ways to reduce household energy use. Secondly, they need to be motivated to save energy. Thirdly, they should be able to adopt the relevant behaviours".

Among others, Frederiks et al. (2015) applied behavioural economics and psychology to highlight the key cognitive biases and motivational factors that may explain why energy-related behaviour so often fails to align with either the personal values or material interests of consumers. However, insight from socio-economic and socio-technical research has recognised that changes in attitudes do not necessarily lead to changes in behaviour, and the choices of individuals are a key factor in the process of energy consumption (Owens and Driffill 2008; Moloney et al. 2010; Elsharkawy and Rutherford 2015).

Strategies to promote efficient behaviour can be divided in two groups, psychological strategies and structural strategies (Steg 2008). While the former (e.g. education, information) are aimed at influencing directly the users, the latter (e.g. new appliances, infrastructures, services) are aimed at changing the context in which decisions are made, to make energy conservation more attractive.

Policy instruments are responsible to translate these strategies into practices. According to Linden et al. (2006), four main categories of policy instruments can be identified, namely information, economic, administrative and physical instruments. Focusing on information, it has been recognised the importance of tailored information (Van Raaij and Verhallen 1983a, b; Abrahamse et al. 2005; Paauw et al. 2009; Barbu et al. 2013) in delivering changes in energy-related behaviours and knowledge. However, information alone is unlikely to motivate changes.

Information is also unlikely to result in sustained behavioural change beyond the life of a given campaign, since enthusiasm for new behaviour or actions tends to decrease in the absence of continual reinforcement (Moloney et al. 2010; Karlin et al. 2015). Although the limits of information strategies (Owens and Driffill 2008), informing the users is recognized an important first step in prompting people to change their behaviour, and an important element in the implementation of policy instruments to lead to reduction of energy consumption in buildings.

Therefore, physical renovation of buildings should be integrated by the information and training on sustainable occupant behaviour, especially in the case of housing stock where low-income people are accommodated, in order to ensure both environmental and social sustainability of the interventions.

2.2.1. Different types of feedback

Individual needs correct information for a responsible choice. Without an appropriate frame of reference, users cannot determine whether their energy consumption can be reduced or not (Gyberg and Palm 2009; Janda 2009; Barbu et al. 2013). Therefore, feedback plays a significant role in raising energy awareness and changing consumer attitudes towards energy consumption. There are a number of different feedback types: direct feedback (e.g. smart meters), available on demand; indirect feedback (e.g. informative energy bills); inadvertent feedback; energy audits (Darby 2006).

Direct feedback is the more immediate and easier accessible means to get on demand information. It is particularly useful for illustrating the impact on energy use of a specific behaviour pattern or device in real time. Feedbacks can be provided by a smart meter with In-Home Displays (IHDs) monitor or a clearly visible energy meter. By direct feedback measures energy consumption information is available in real time, all the times. Nevertheless, the effect of the direct feedback depends on how regularly users read the information, and also the literature (Fischer 2008; Barbu et al. 2013; Karlin et al. 2015) emphasizes the importance of frequent feedback in order to effectively influence user behaviour.

Indirect feedback is the one that has been processed in some way before being delivered to the users, as the case of informative energy bills. Consumers have no direct access to the real time consumption of a certain behaviour pattern and can only respond to previous consumption behaviours. This means that there is a time-delay between energy consumption and the moment the feedback reaches consumers. The means for providing indirect feedback can vary from more informative and also more frequent bills, information on web platform and email. As indirect feedback can include analysis of data collected over longer period, it is more suitable for showing longer-term effects. As for the direct feedback, the effect of indirect feedback depends on how frequent the feedback is available for consumers, and on how simple the information is.

Fischer (2008) summarised the knowledge about the qualities of "successful" feedback, acknowledging gaps in the research literature. Ideally, such feedback includes at least two of the following characteristics: multiple options for the user to choose from; an interactive element; frequency more often than monthly (continuously, daily load curves, or immediately after the action – switching on or off); detailed, appliance-specific breakdown of usage, and comparisons with previous periods. Faruqui et al. (2010) found that direct feedback provided by In-Home Displays (IHDs) can encourage occupants to make more efficient use of energy. Energy savings from occupant behaviour range between 3% and 13%, with an average of 7%. The range of savings achieved through indirect feedback (2%-10%) tends to be lower than the one reported in direct feedback studies (5%-15%); nevertheless, they may be important and are achievable at relatively low cost. Moreover, the combination of different informational feedback may lead to an increase of energy savings up to 20% (Barbu et al. 2013).

Jain et al. (2013) gave an insight on the impact of information representation on user behaviour. Their experiment in USA provided two study groups with real energy consumption data but according to different unit of measurement. Users who received feedback in terms of the environmental externality unit (i.e., trees needed to offset emissions) on average were able to save more energy than the group who received the feedback in the direct energy units of kWh. Frederiks et al. (2015) concluded that advising individuals that people similar to them (e.g. peers, neighbours) are using less energy or taking certain energy-saving actions, in addition to conveying social approval of such actions, will most likely motivate them to conform to these positive energy-saving attitudes and to reduce their consumption accordingly. The use of the energy bills in heating, domestic hot water and electricity saving measures may seem obvious. They are the occupant factsheets on how much energy they consume. The energy bill can also be used as a communication tool for saving tips, but for being an important saving measure, the information must be easy to understand for those it is aimed at. Henryson et al. (2000) have reported that the 67% of people interviewed think that bills should contain simple information on energy-savings, as the highest motivation to absorb them, occurs at their time of arrival.

However, providing a household with information tends to result in higher knowledge levels, but not necessarily in behavioural changes or energy savings (Abrahamse et al. 2005; Steg 2008; Moloney et al. 2010; Elsharkawy and Rutherford 2015). Statistics from seven public housing companies using individual metering and billing for heating in about 7,800 apartments in Sweden have indicated that most residents in these buildings have chosen an indoor temperature of around 21–22°C, slightly higher than the temperature of 20–21°C supplied in the buildings of property owners without individual metering and billing for heating (SABO 2016).

Inadvertent feedback occurs when community energy conservation and energy behaviour awareness campaigns are implemented. Increasing understanding and knowledge through inadvertent feedback can also apply in case of energy microgeneration, when housing buildings become sites for generation as well as consumption (Darby 2006). The Energy Cultures research project (Barton et al. 2013) found that family and friends are the key influences on household energy behaviour changes, more so than media, community action groups or other organisations such as councils or energy companies.

Energy audits are also an additional means to provide detailed information on energy demand and saving potential. They generally include the evaluation of the thermal characteristics of the building, its HVAC system and the appliances in use. Although the energy audit report does not address user behaviour directly, it can be successful in raising awareness on energy issues, a prerequisite for changing behaviour and consumption practices.

2.3. Community-based initiatives and behaviour change

There is a growing interest in applying insights from behavioural sciences to the design of policies and strategies for urban regeneration, but the potential to fully combine these insights within environmental and climate policy has not yet been fully explored. At the same time, in the wider discussions on design for policy and sustainable behaviour change, community behaviour change is an issue underexplored. Much of the research on and policy interventions for behaviour change are focused on individual rather than collective behaviour (Moloney et al. 2010; Karvonen 2013; Gram-Hanssen 2014). Defining sustainable communities can be a challenging issue, very much related to the context and the purpose of the investigation. Communities take many forms and exist over different levels (e.g., local, global), different spatial settings (e.g., urban and rural) and they are dynamic and constantly changing. In the broadest sense, sustainable communities actively and cooperatively work to reduce their environmental impacts both locally and globally, and to foster economic and social wellbeing. From a theoretical point of view, sustainable communities can be described either from the perspective of infrastructure and planning (e.g., neighbourhoods, land-use policy, housing) or from the social context by focusing on social relations, social practices, lifestyles and governance. From the citizen perspective, reflecting on complex issues as sustainability, climate change and regeneration from the communities' perspective can help to ground the actions and to make them more tangible.

Regenerating existing communities through the increase of energy efficiency in buildings and actions to support a sustainable lifestyle requires the participation of individuals prepared to embrace change and to support the transformation process that can last several years. In the field of energy research both on policies and buildings, informational feedback has a leading role in moving towards efficient behaviours. However, although the feedback approach is recognised to be useful, there are other factors that influence household consumption that may not be affected by this mechanism (Janda 2009). In order to make people taking responsibility for their role in the built environment, education has to be more comprehensive and to go beyond the house walls.

There is a growing body of science claiming for the shift from behaviour to practice (Gram-Hanssen 2010; Hargreaves 2011; Shove and Walker 2014). The transition towards changing and sustaining a new set of social practices rather than changing some behaviours in the short term will be necessary to see significant reductions in environmental impact over time (Moloney et al. 2010). Gram-Hanssen (2010) conducted a research on heating consumption in residential sector and defined five ideal types of families and how they relate to residential heat comfort by applying practice-theory approach. Although the five types do not necessarily represent all possible groups, they do show important aspects and variations of comfort practices. The results suggested to learn from the four elements holding the practices together (i.e., technologies, knowledge, habits, and meanings), instead of looking for an exhaustive classification of behaviour patterns.

Community-based initiatives represent the step required for moving from behaviour change to systemic change. Being adopted by an increasing number of programmes, they have the potential to establish ownership and responsibility for actions to pro-environmental behaviour change, even in situations where individuals may otherwise feel that their contribution is insignificant. Compared to programmes addressing individual consumer behaviour, community-based programmes are more likely to address the more challenging social, institutional and technical barriers and constraints (Moloney et al. 2010). Moreover, community-based programmes are able to achieve multiple benefits in the same environment, resulting in high level of awareness on risks and barriers to the effective implementation of renovation programmes. The non-energy co-benefits are even more important in the social housing sector where energy efficiency of buildings and fuel poverty only represents one issue of a complex framework (Heffner and Campbell 2011; Santangelo and Tondelli 2017a; Santangelo et al. 2018) However, low income energy efficiency programmes have traditionally been evaluated based on energy savings for participating households, by comparing household energy savings or bill reductions with the annual programme spending to determine whether an energy efficiency programme is cost effective. On the contrary, programme evaluation frameworks should take into account the non energy co-benefits that can result from such programmes.

2.3.1. Suggestions for community behaviour change initiatives

While an exhaustive summary of all possible initiatives is beyond the scope of this chapter, there is a need to understand how to guide the effective design and delivery of community-focused strategies and public policy interventions to implement urban regeneration, particularly through actions that capitalise the resources to mobilise further changes. Indeed, throughout the following discussion, interventions on energy-related behaviour are suggested in order to stimulate and to activate further regeneration processes. In this respect, energy can be considered as a driver to urban regeneration, while addressing attitudes and behaviour change is a prerequisite for co-creating and co-implementing regeneration strategies (Santangelo and Tondelli 2017b). As result of literature review, investigation of behavioural determinants and patterns analysed in the previous sections, some key elements for successful behaviour change initiatives are summarised and proposed below.

- Providing simplification strategies to facilitate more effective decision-making. Simplification strategies may help to reduce cognitive overload and facilitate more effective decision-making in regard to energy consumption – such as making a desired action easier, quicker and more convenient, minimising the physical and psychological demands needed to perform the action (e.g., making it the default) and reducing perceived uncertainty (e.g., encouraging people to try a new activity in a risk-free environment) (Steg and Vlek 2009). Unnecessary complexity and sensory overload should be avoided by framing messages in a clear, concise and comprehensible format. In terms of relaying information to consumers, keeping things short and simple is essential for effective communication. For example, avoid inundating people with too many energy-saving tips or too many choices, instead presenting smaller amounts of the most important information. Indeed, laboratory experiments and field studies have found that having more choices is not necessarily more desirable, appealing or intrinsically motivating, and people may even perform better in limited-choice contexts. Rather than delivering information-intensive campaigns and complicated users education programmes, behavioural strategies should instead focus on communicating simple messages that the average consumer can quickly and easily understand.

- Incorporating examples of energy-saving actions in user-focused messages to make them easy to remember and especially salient. In situations where people simply forget to perform energy efficient behaviours, basic visual or auditory reminders can prompt consumers to act.
- Framing energy-saving messages in terms of avoiding or minimising prospective costs and losses, as this may catch the attention and make the information more motivating (Frederiks et al. 2015). Rather than putting emphasis on saving energy, communication should focus on the costs (i.e., time, effort, money) associated with energy-wasting practices and highlight how pro-environmental behaviour will prevent future losses and costs. A previous research (Gonzales et al., 1988) had already suggested that, when communicating messages to improve energy efficiency in dwellings, framing recommendations in terms of loss (i.e., energy and money lost if people do not take actions) rather than gain (i.e., energy or money gained by taking actions) may be more effective.
- Framing energy-saving practices as both common and socially desirable. For example, advising consumers that people similar to them (e.g. peers, neighbours) are using less energy or taking certain energy-saving actions, in addition to conveying social approval of such actions, will likely motivate them to conform to these positive energy-saving norms and to reduce their consumption accordingly. According to the results of a study conducted by Frederiks et al. (2015), households who received descriptive normative messages (e.g. information comparing a household energy usage to that of neighbours) used significantly less energy in the short-term compared to householders who only received energy saving tips.
- Creating a shared group identity within the community where people can feel their individual contribution as important, and emphasising that many other

consumers are also actively saving energy (i.e., capitalising on descriptive social norms), may help reduce free-riding and social loafing in group settings. Making any shared outcomes or collective achievements more salient, and publicly acknowledging the efforts of individuals, may also help motivating people to contribute to the greater goal.

- Information strategies must avoid to "blame the victim" and simply suggest trying harder. A successful approach should allow inhabitants to feel empowered, rather than guilty (Stevenson and Leaman 2010).
- Behaviour is more likely to be deliberately considered and changed when a discontinuity occurs in the household context (Huebner et al. 2013). Therefore, building renovation programmes are the key opportunity to involve households in order to make them reconsider their consumption practices. However, pro-environmental behaviour is likely to be taken into account if information and education measures come from credible, trustworthy sources. Thus, within the social housing sector, the impact of sustainable community programmes is closely linked to the relationship between social housing tenants and providers.

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››› 3. Investigating the impact of behaviour on household energy consumption

The identification of major determinants of building energy consumption, and the thorough understanding of their impacts on energy consumption patterns, could assist in achieving the goal of improving building energy performance and reducing greenhouse gas emissions due to the building energy consumption.
Especially when it comes to energy retrofit of buildings, the main issue policy-makers are struggling with is to understand which measures offer the greatest benefit within the framework of interacting environmental, economic and social factors. In fact, when it comes to increase the sustainability of cities, an economically oriented cost-benefit analysis alone is not adequate to take into consideration the multiplicity of determinants towards an energy efficient building stock.
This chapter aims to understand the impact of consumer behaviour on household energy consumption. To do so, two different approaches to data analysis are introduced, depending on the availability of data and their accuracy, and their relevance when it comes to gain information to design policy instruments to build energy awareness among households. Then, three main steps are further described. At first, statistical data on energy consumption in buildings from the Italian statistical bureau are analysed to identify behavioural characteristics influencing energy consumption. The following part is aimed at providing evidence to the policy-makers of the importance of tackling behaviour into account in the design and implementation of the renovation strategies for the existing housing stock. The role of occupant behaviour modelling in supporting decision-makers dealing with the design of renovation strategies for residential buildings is investigated by assuming an Italian multi-family public housing building located in Bologna as case study. Finally, a methodology based on multi-criteria assessment of different strategies by applying the Analytic Hierarchy Process (AHP) is performed and the impact of renovation measures addressing consumer behaviour in different scenarios is described.

3.1. Different approaches to data collection and analysis

According to Bedir (2017), the methodology for modelling the influence of occupant behaviour on the energy performance of buildings follows two main approaches: the deductive approach and the inductive one. The former uses the data on household characteristics, energy consumption and income level to find statistical correlation between energy use and occupant behaviour, whereas the latter calculates the building energy consumption based on actual occupancy and behaviour patterns determined by presence, circulation, and operation of lighting, system control devices and appliances. Survey collecting cross-sectional data is the most common method of collecting data in the deductive approach, and statistical models are claimed to be faster and easier tools than simulation models to predict energy consumption in large sample size. However, in the inductive approach, monitoring and/or observation of behaviour are preferred, while simulation tools can help in modelling detailed aspects of behaviour in a way that statistical models ignore (Bedir 2017; Hong et al. 2017).

According to the size of data and the level of accuracy, different approaches to data analysis can be applied. Hereafter, two main approaches are described.

The first one relies on large sample size, collected either through national statistical survey with heterogenous data on energy consumption, building characteristics and household characteristics, or through data from the building monitoring system. This approach does not require ad-hoc survey or the *ex-ante* definition of variables, but can be performed using data coming from different sources, as long as the relevant information is available. Occupancy pattern can be identified by applying statistical analysis such as correlation, regression, analysis of variance (ANOVA), or through data mining and machine learning techniques. The objective of this approach is usually to understand the determinants of behaviour in order to define more accurate occupancy profiles per household type that can lead to more realistic predictions of energy demand. In particular, analytical techniques for big data, such as data mining, have the capability to provide qualitative and quantitative information on diverse user profiles in a block of buildings, enabling the use of more realistic 24-h schedules in building performance simulation tools (Ren et al. 2015). Indeed, data mining techniques are not intended as a substitute to or contrast with direct stochastic modelling approaches. So far, it has been largely applied to research fields such as marketing, medicine, biology, engineering and social sciences, while the application to building energy consumption and operational data is still in the starting phase (D'Oca and Hong 2015).

The second approach is project-based, it does not necessarily require a large data sample, but questionnaires need to be designed taking into account the specific characteristics of the surveyed sample. Both quantitative and qualitative analysis can be performed, depending on the starting pool and the response rate. The results of surveys might help to establish a modelling framework, though they do not provide the resolution of data required for building detailed statistical models that sensors can provide (Yan et al. 2015). While the first approach can trace general trends, or discover some unexpected relations, the second one is mostly used to provide evidence on the strengthens or weakness of relations already assumed. Despite the revealing nature of surveys and interviews, there are some fundamental issues that need to be taken into account, as participants misrepresenting their behaviour or not recalling it, or responding the way they think they are expected to.

The two approaches are described below and the use of statistical data to investigate the human factor in energy consumption is further explored.

3.1.1. Understanding user behaviour and awareness through statistical data

Previous studies have highlighted that building characteristics explain only between 40% and 54% of variation in energy use (Sonderegger 1978; Guerra-Santin 2010). Scholars have agreed that, as the thermal properties of buildings improve, the impact of building characteristics decreases, making occupant behaviour more relevant. Furthermore, the relative impact of occupant characteristics and behaviour seems to differ in various studies confirming the importance of contextual analysis (Mora et al. 2015).

Statistical analysis has been found to be powerful tool to investigate the role of household behaviour in influencing energy consumption in residential buildings (Andersen et al. 2009; Guerra-Santin and Itard 2010; Mora et al. 2015; Schaffrin and Reibling 2015; Guerra-Santin and Silvester 2016). Among them, Andersen et al. (2009) conducted statistical analysis starting from survey results in Danish dwellings on occupant control of the indoor environment. Results have shown that window opening behaviour was strongly linked to the outdoor temperature, while, among household characteristics, the gender of the respondent and the perception of environmental variables (IAQ, noise and illumination) also affected the proportion of dwellings with open window. The average age of the inhabitants, the thermal sensation of respondents and gender also had an influence on the use of lighting. Mora et al. (2015) conducted a study to determine the influence of physical and behavioural selected factors in energy buildings performance in Mediterranean climate, starting from a survey-based data collection. The variables considered were classified into three categories: physical, occupants and energy. The results revealed that floor area and climate are the most significant physical parameters for electricity consumption; age, number of household members and income can be mentioned concerning the occupants. Other studies were conducted by starting from larger dataset, as the case of Guerra-Santin and Itard (2010) using Dutch dataset from statistical survey conducted at national level. In this study, results showed that the number of hours the heating system operates has a stronger effect on energy consumption than temperature setting. The main building characteristic determining behaviour turned out to be the type of temperature control. Households with a programmable thermostat were more likely to keep the radiators turned on for more hours than households with a manual thermostat or manual valves on radiators. In relation to household characteristics, the presence of elderly proved to be a determining factor in the use of the heating system and ventilation. As a result of wide variations in preferences and lifestyle, occupant behaviour has emerged as an important contributor to energy use in dwellings.

3.1.2. Understanding user behaviour and awareness through questionnaires

Many studies have investigated people behaviour in residential buildings, and most of them recognised that physical conditions are not the only variables influencing the behaviour of building occupants. They have resulted in new understanding of household and building determinants and human behaviour patterns definition in relation to window opening, use of air-conditioning and temperature control, lighting and solar shading, depending on outdoor and indoor conditions. Among them, a consistent number has adopted survey methodologies to understand household awareness, behaviour and willingness to adapt to more sustainable consumption patterns. They main consist of questionnaires (Andersen et al. 2009; Gupta and Chandiwala 2010; Frontczak et al. 2012; Huebner et al. 2013; Feng et al. 2016), in-dept interviews (Gram-Hanssen 2010; Hayles and Dean 2015) and there have been also studies combining both (Peters et al. 2010; Brown et al. 2014), to get a deeper understanding. In case a disruptive change occurs, as the housing renovation to improve energy efficiency of building components, and installation of new technology systems as smart meters, some scholars have highlighted the importance of performing post-occupancy evaluation (Bordass and Leaman 2005; Hendrickson and Wittman 2010).

In some cases, the questionnaire based survey are preferred for reducing the direct-personal observation effects which causes the participants to feel observed and, therefore, alter their responses (Wilhite and Ling 1995; Vassileva and Campillo 2014; Boemi et al. 2017). In others, sending email instead of delivering the questionnaires by hand at home or by post has resulted to be effective in enlarging the target group reached (Jain et al. 2012; Feng et al. 2016). The survey tool has also been applied at community scale, rather than individual one, to determine their level of interest in the municipal Green Living Centre in London by distributing the questionnaires to visitors (Peters et al. 2010).

Due to the time people spend in indoor environment, and considering they have the greatest freedom to act and the greatest control at home, the residential sector is the one where user behaviour has been investigated the most, since raising awareness among households on their consumption behaviour patterns at home is believed to be a crucial point in lowering energy consumption (Hayles and Dean 2015). Therefore, studies performing survey-based investigations have mostly focused on the residential sector (Shipworth et al. 2010; Vassileva and Campillo 2014; Elsharkawy and Rutherford 2015; Hayles and Dean 2015; Feng et al. 2016), although the number of scholars working on assessing behaviour impact on office buildings through survey is also increasing.

3.2. Analysing Italian statistical data to identify household characteristics influencing behaviour

3.2.1. Italian building stock and energy efficiency trends

According to the Italian Statistic Bureau (ISTAT 2014), in Italy there are 14.5 million buildings, and more than 84% of them are residential buildings. Approximately half of the housing stock consists of apartments in multi-family buildings, a figure that increases particularly in metropolitan areas, where this share reaches 85.5% of the total housing stock. However, Italian multi-family buildings are rather small and low-rise, with high surface-area-to-volume ratio, resulting in very likely high thermal dispersions. When it comes to the quality of the Italian building stock, it is quite old and not adequately refurbished. More than 75% of households live in buildings built before 1990, with low efficiency rate, high maintenance costs for the owners and high energy costs for the households. Approximately 740,000 buildings are not used, due to the need of renovation interventions or poor safety conditions (ISTAT 2014).

For what concerns the energy performance, in 2015 the Italian building sector was responsible for 42% of the total final energy consumption. The same year, the residential sector accounted for 28% of the total final consumption. According to the last available country profiles of Odysee-Mure (2018), the Italian final energy consumption was 116 Mtoe, with a reduction of 7% compared to 2000. However, over the period 2000-2015, the residential sector recorded a 6% of increase in its share of final energy consumption, and it was the only sector with increasing energy consumption from the reference year 2000, despite the economic crisis. Space heating accounted for 68% of energy consumption followed by water heating (12%), electrical appliances (11%), and cooking (6%). Air-conditioning (3%), has more than doubled since 2000. The increased energy consumption in residential sector was mainly due to two factors: the increased number of dwellings that have been built and the greater comfort that they required, mainly due to more appliances per dwelling.

According to Nomisma (2016), in 2014 about 72% of households own their house, despite the real figure is closer to 80% due to the rate of households living in their house according to other types of tenure (e.g. bare propriety, family house) (9.6%), that can be assimilated more to the homeowners than to the renters. This large share of homeowners implies that dwelling renovation interventions are rather frequent, much more than the realisation of new buildings. Indeed, the 67% of the construction market consisted in 2012 of renovation of the existing stock, although these interventions have been mainly on technical systems or aesthetic enhancement and not aimed at improving the building energy performance (Caputo and Pasetti 2015). These energy efficiency interventions, which accounted for 3.7 billion euro of investments in 2017 for implementing about 420,000 interventions, are carried out mainly when there is a failure of the technical systems, a need to upgrade them, or when owners want to take advantage of government incentives. In fact, incentives for energy-saving measures have resulted in single interventions, rather than in a whole building approach, since the overall renovation measures for the period 2014-2017 accounted only for 8.9% of the total energy efficiency investments (ENEA 2018). Among the resources allocated in the period 2014-2017, over 6 billion euro involved the replacement of over 2.6 million windows (i.e. 46% of total investments), while over 2.1 billion euro have been allocated to around 70,000 interventions on roofs and slabs. In 2017, approximately 40% of investments (over 1.4 billion euros) concerned a detached or semidetached house, while about 35% of the resources (about 1.3 billion euros) involved blocks of flats with more than three floors. Thanks to the Italian Ecobonus scheme (ENEA 2018), in 2017 the estimated energy reduction accounted for 1,300 GWh/y. In the timeframe 2014-

2017, energy retrofit of buildings and other energy efficiency interventions have led to an average saving on the annual energy bill between 250 euro in 2014 and 150 euro in 2017, also due to the different levels of gas prices, saving on average the 15% of the total annual energy expenditure of households.

Nevertheless, this renovation is usually limited to single housing units instead of involving the whole building. Indeed, propriety fragmentation can be considered one of the main barriers to comprehensive building retrofitting and urban regeneration.

Low awareness among homeowners and lack of skills of building managers are also some of the causes. Building managers, in particular, have very often neither competences nor the professional interest to support the owners in the improvement of the building stock. On the contrary, since in Italy for buildings with more than 8 owners is mandatory by law (i.e. L. 220/2012) to appoint a building manager, who is responsible for the management and maintenance of the heating systems and for the building energy certificate, it could be useful to extend his/her duties to the overall building efficiency and energy micro-generation, in cooperation with an energy manager. For smaller buildings, the management is directly done by one or multiple owners, with less people to come to an agreement about building retrofit, but with the same situation in terms of lack of awareness on energy efficiency measures, benefits and procedures.

3.2.2. Data sample

As there are significant differences in energy consumption between households, it is increasingly important to get a clear insight into the relationship between type of occupancy, household characteristics and energy use. When it comes to the renovation of the existing housing stock, more certainty on the occupancy behaviour and determinants explaining it, before the renovation is conducted, can potentially help to reduce the financial risk associated with the interventions. For instance, the payback time and the prebound effect (Sunikka-Blank and Galvin 2012; Guerra-Santin and Silvester 2016) are strictly related to user behaviour, where the latter consists of households using less energy than foreseen due to energy poverty condition and low awareness of energy efficiency technology use. To investigate heating patterns and occupancy attitude in relation to the Italian household composition in the Italian context, the results from the Household Energy Consumption survey[1] performed by the Italian Statistic Bureau (ISTAT) in 2013 have been analysed. The survey was conducted from March to July 2013 by applying the CATI (Computer assisted telephone interviewing) technique. The survey has been the result of the agreement jointly signed in 2011 by ISTAT and the Italian National Agency for New Technologies, Energy and Sustainable

1 Indagine Sui Consumi Energetici Delle Famiglie. The statistical analysis that follows only represent the author's elaboration and ISTAT is not liable for any use that may be made of the information contained therein. For more information on survey methodology, questions and variables list, see: https://www.istat.it/en/archivio/203349.

Economic Development (ENEA) to investigate the energy consumption in the residential sector. It has been conducted aiming at providing, for the first time in Italy, accurate statistical data on the energy behaviours of households living in Italy, filling the information gap at national and also international level. The resulting dataset includes information regarding household composition, housing needs, energy consumption, building characteristics and building operation. The sample population has been randomly selected from the official archive of households subscribing to the telephone network. The total responses consist of 20,000 records, coming from the 20 Italian Regions and 8,000 Italian municipalities with different sizes, from metropolitan areas to remote rural areas having less than 10,000 inhabitants, both in mountain and coastal areas.

To the aim of this research, only elements related to the heating consumption have been investigated. The descriptive statistics of household type, household characteristics and dwelling characteristics are presented in Table 3.1 and Table 3.2. The dataset embeds a series of limitations: first of all, information on household expenditures is expressed in a categorical non-fully-ordinal variables, which do not allow further analysis on the energy costs. In fact, besides being reported in categorical variables, the yearly costs for heating consumption are taken into account according to the type of fuel (i.e. gas, petroleum, LPG) instead of the type of end-use (i.e. space heating, water heating, cooking) with different categories among the variables (e.g. from 1 to 12 for the gas from network system, from 1 to 10 for petroleum, from 1 to 7 for LPG), and different sizes among the categories themselves, resulting in no possibility to sum them. Secondly, the dataset does not include information on energy expenditures for dwellings with a building centralised heating system operating, although the related question was included in the survey. Therefore, respondents with centralised heating system have been excluded from further analysis, as well as households who do not use the gas supply network for heating, and the sample size is reduced to 13,005 samples.

The average size of the households is 2.7 persons, while the average age of the household head is 57 years old. At least one senior occupant older than 65 is part of the 59% of the total households, while about 1/3 of the families have at least one member less than 20 years old. When it comes to the working condition, a crucial parameter directly influencing the household occupancy attitude, 3 out of 4 households have at least one retired and/or unemployed person and/or housewife. The education level has been also investigated, resulting in almost the same number of households with all high school graduated members and the ones with at least one university graduated person, while the great majority (72%) has at least one member without high school certificate. In terms of gender, households with a prevalence of male members are 23%, while the ones with a prevalence of females account for 29%, although almost half (48%) of the households have a gender balance situation.

When it comes to the dwelling characteristics, the largest share (i.e., more than 4,700 households, 37%) lives in buildings built between the seventies and the nineties, while the single/multi-family house with one or few housing units is the

Table 3.1. Descriptive statistics of variables on household characteristics and building characteristics. Source: author's elaboration on ISTAT microdata

Household characteristics				
Continuous variable	**Definition**	**Mean**	**SD**	**N**
Household size	No. of household members	2.68	1.17	13,005
Age	Age of household head	57.24	12.84	13,005
Categorical Variable	**Definition**		**%**	**N**
Household composition	At least one senior (> 65 years old)		59	7,636
	At least one member between 45-65 years old		57	7,437
	At least one member between 20-45 years old		30	3,938
	At least one young person (< 20 years old)		34	4,449
Working condition	At least one retired and/or unemployed person and/or housewife		75	9,788
	Only working adult(s)		15	1,979
	Households with only working adult(s) and/or student(s)		10	1,238
Education level	Lower (not all members with high school qualification)		72	9,313
	Middle (all household members with high school qualification)		29	3,694
	Higher (at least one household member with university degree)		29	3,738
Gender	Prevalence of male		23	3,047
	Prevalence of female		29	3,780
	Equality		48	6,199
Dwelling characteristics				
Continuous variable	**Definition**	**Mean**	**SD**	**N**
Dwelling size	No. of rooms	3.60	1.27	13,005
Categorical Variable	**Definition**		**%**	**N**
Type of dwelling	Single/multi-family house with one or few housing units		53	6,961
	Dwelling in multi-family building up to 10 housing units		29	3,710
	Dwelling in multi-family building between 11-27 housing units		15	1,953
	Dwelling in multi-family building with more than 27 housing units		3	381
Year of construction	Before 1950		18	2,403
	Between 1950-1970		24	3,116
	Between 1970-1990		37	4,772
	After 1990		21	2,714
Dwelling size	Up to 59 m^2		4	537
	Between 60-89 m^2		27	3,462
	Between 90-119 m^2		39	5,081
	More than 120 m^2		30	3,925
Thermostat regulation	Yes		83	10,734
	No		17	2,271

Table 3.2. Descriptive statistics of energy consumption and behaviour. Source: author's elaboration on ISTAT microdata

Energy consumption				
Categorical Variable	**Definition**		**%**	**N**
Energy expenditure for heating from gas supply network	Up to 600 €/year		17	1,901
	Between 600 and 1,000 €/year		31	3,349
	More than 1,000 €/year		52	5,733
Behaviour and awareness				
Continuous variable	**Definition**	**Mean**	**SD**	**N**
Heating system	No. of operating hours between 5 am and 1 pm	2.34	2.13	12,386
	No. of operating hours between 1 pm and 9 pm	4.22	2.07	12,386
	No. of operating hours between 9 pm and 5 am	1.05	1.53	12,386
	No. of operating hours per day	7.62	4.30	12,386
Categorical Variable	**Definition**		**%**	**N**
Awareness of building energy label procedure	Yes		43	5,591
	No		57	7,414

most prevalent housing type (53%). Dwelling in multi-family building up to 10 housing units represents the 29% of the total, confirming that Italian families live in low-rise buildings. More than 9,000 households live in housing units larger than 90 square meters, and, if considering the whole sample, the average number of rooms is slightly more than 3 and a half.

More than a half of households spend more than 1,000 €/year for heating from gas supply network, while the 30% spend between 600 and 1,000 €/year. However, as already explained, the information about energy expenditure does not allow further investigation on the influence of household characteristics and building characteristic on energy costs.

Indeed, some more considerations can derive from the analysis of data concerning the number of operating hours of the heating system. Since the analysed data only include households who can decide by their own when to turn on and turn off the heating system, this variable is even more representative of the behaviour than energy expenditure. As shown in Table 3.2, the heating system is turned on, on average, for less than 2 hours and a half during the morning (i.e., from 5 am to 1 pm), more than 4 hours in the afternoon and evening (i.e., from 1 pm to 9 pm) and for about 1 hour only during the night (i.e., from 9 pm to 5 am), resulting in a total average of 7.62 hours during a day. However, the survey did not make any distinction between workdays and weekends, therefore, this results in an average estimation.

The awareness of building energy procedure is one of the very few questions aimed at investigating household knowledge and awareness towards energy savings. According to the results, 57% of respondents are not aware about the

Table 3.3. Descriptive statistics of variables selected. Data for Emilia-Romagna Region only. Source: author's elaboration on ISTAT dataset

Continuous variable	Definition	Mean	SD	N
Household size	No. of household members	2.45	1.14	860
Categorical Variable	Definition		%	N
Household composition	At least one senior (> 65 years old)		52	449
	At least one member between 45-65 years old		63	545
	At least one member between 20-45 years old		27	230
	At least one young person (< 20 years old)		23	199
Gender	Prevalence of male		26	220
	Prevalence of female		33	285
	Equality		41	355
Working condition	At least one retired and/or unemployed person and/or a housewife		71	612
	Only working adult(s)		20	171
	Households with only working adult(s) and/or student(s)		9	77
Education level	Lower (not all members with high school qualification)		73	631
	Middle (all household members with high school qualification)		27	230
	Higher (at least one household member with university degree)		27	229
Thermostat regulation	Yes		83	718
	No		17	142

procedures. Questions regarding the dwelling energy class have been included in the survey, however the answers have not been processed and included in the dataset, making impossible to formulate more considerations on the energy efficiency of buildings can be performed.
Certainly, as the energy expenditures depend on the final price of the energy utilities, the number of operating hours of the heating system is related to the climatic conditions. Italian climate shows significant differences between the inlands and the coastal areas, both from north to south and from east to west. The national territory is divided in 6 climate zones (A–F) defined according to heating degree days (HDD) as established by the national regulation (DPR 412 1993). The HHD represents the sum –extended to all days in a conventional annual heating period – of positive differences between interior temperature (conventionally fixed at 20 °C) and the mean daily external temperature. For every zone, the norm fixes the period of the year and the maximum number of hours per day that heating may be switched on.
To reduce, on the one, hand the degree of influence of the location on the heating system, and on the other hand, the sample size to avoid the normalisation of the results, due to the low degree of variability in the attributes (Israel 1992), only data for Emilia-Romagna Region have been further processed, since more than

85% of municipalities in this region are located in the E climatic zone. The dataset further reduced to 860 samples, is now much more closer to similar studies (Andersen et al. 2009; Mora et al. 2015; Guerra-Santin and Silvester 2016) in terms of size. The variables further considered are the one in Table 3.3, where data for Emilia-Romagna Region only are illustrated.
Building characteristics have not been included in the investigation since the focus of this part of the study is on the household determinants. Much is already evident about the link between energy efficiency of building and behaviour, while household characteristics causing certain behaviour patterns are generally salient and need to be further investigated.

3.2.3. Results from the statistical analysis

The relationship between the use of the heating system and household characteristics has been analysed. The household characteristics taken into account are: age, gender, education level, household size and working condition. The possibility to regulate the thermostat has been added to the selected variables. The statistical tests applied are related to the type of variables. Household characteristics are mostly in categories (see Table 3.3), while the use of heating system is expressed in hours, so in continuous form. For the only parametric variable in normal form (i.e., household size) Pearson product-moment correlation coefficient has been used to determine the effect on heating system operating hours. It is a measure of linear dependence between two variables with a value between -1 and +1. The t-statistic aims to analyse the differences between the means of two groups; if t-statistic is less than the significance level (or error), the null hypothesis is rejected. Independent-samples t-tests have been used to determine the differences on behaviour in dichotomous variables (i.e., thermostat regulation). One-way ANOVA tests have been used for categorical variables with more than two levels. The one-way ANOVA is used to determine whether there are any significant differences between the means of three or more independent groups. Statistical analysis results are presented in Table 3.4.
Household size turned out to be unconnected to the number of operating hours of the heating system. No correlation was found between the two variables ($p=0.021$).
An independent-samples t-test uncovered a relationship between the presence of thermostat regulation and the number of hours that the heating system operates. The presence of thermostat regulation is related to less operating hours of the heating system. Household composition according to age also turned out to be a statistically significant variable, with households having at least one senior with more than 65 years old using the heating system for more hours than other family groups.
As expected, the working condition resulted to be also a statistically significant variable. Although no specific questions were asked regarding typical occupancy patterns, the results from the one-way ANOVA test shows that households with at least one retired and/or unemployed person and/or a housewife operate the heating system more than one hour and a half longer than households where all the members work and likely stay out from home most of the day, while families

Table 3.4. Statistics from independent t-tests and one-way ANOVA tests for selected variables related to behaviour about operating hours of the heating system. Source: author's elaboration on ISTAT microdata

Variable considered in relation to behaviour	Statistics	Categories	Mean	SD	CV
Thermostat regulation	t= -2,00 p<.05	Yes	9.08	4.63	0.51
		No	10.27	4.34	0.42
Household composition	F(3,1419)= 3.460 p<.05	At least one senior	10.21	4.72	0.46
		At least one member 45-65 years old	9.36	4.38	0.47
		At least one member 20-45 years old	9.63	4.40	0.46
		At least one young person	9.30	4.60	0.49
Gender	NS	Prevalence of male			
		Prevalence of female			
		Equality			
Working condition	F(2,857)= 10.22 p<.001	At least one retired and/or unemployed person and/or a housewife	10.07	4.64	0.46
		Only working adult(s)	8.32	3.89	0.47
		Households with only working adult(s) and/ or student(s)	9.55	4.44	0.46
Education level	NS	Lower			
		Middle			
		Higher			

SD = standard deviation; CV = coefficient of variance; NS = not statistically significant

without retired and/or unemployed person and/or a housewife but with students turn the heating system on for approximately the same time than the first group. One-way ANOVA tests determine that neither education is statistically significant (F(2,1086)=2.457, p=0.08) when it comes to the number of hours in which the heating system operates, nor gender (F(2,856)=1.09, p=0.34).

Figure 3.1 shows the relationship between occupant behaviour and household characteristics. Absence of thermostat, household composition and working condition affecting presence at home are all related to more hours on the use of the heating system.

The results seem to be in accordance with the findings of other studies, although the variables that have been possible to consider in this research are much less than the ones investigated in other studies conducted abroad, where more accurate statistical data are available. The results show that household composition in relation to age is a statistically significant variable, with seniors having more energy-intensive heating practices in terms of number of hours the

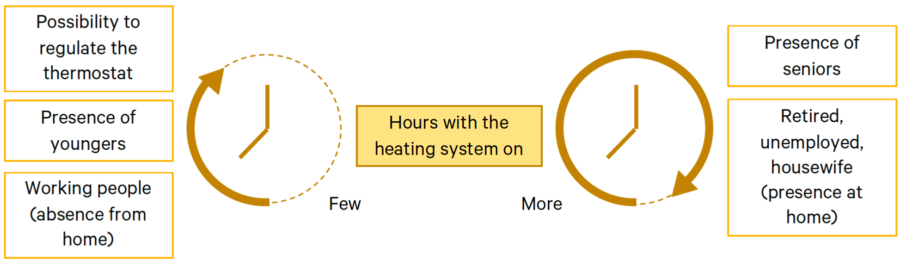

Figure 3.1. Relationships between type of temperature control, household characteristics, and use of heating system. Source: author's elaboration.

heating system is turned on than households with younger occupants up to 20 years old. The differences in heating behavioural patterns seem to be caused by differences in lifestyle between households (e.g., hours at home due to the working condition), and household composition (e.g., presence of seniors or youngers). However, there are certainly other household conditions that could also affect the occupancy patterns for heating, that this investigation could not reveal.
Although the survey has been expressly delivered to collect information on household behaviour and building characteristics causing energy consumption and energy expenditures, it missed the opportunity to get a proper insight into the behaviour itself, the occupancy patterns, the household awareness and attitude towards energy efficiency. The energy costs express in macro-category not even fully-ordinal (i.e., in case of gas use from supply network, the range in euro of the category no. 12 embeds within itself the categories no. 9, 10 and 11) does not allow to investigate the relationship between household characteristics and energy expenditures. Moreover, the data on energy consumption in energy unit are completely missing, as the data on energy efficiency of the dwellings, although the latter issue is part of the questions, but not part of the micro data. Also, data on energy expenditures for the centralised heating system have turned to be not available in the dataset, resulting in the impossibility to investigate household characteristics related to behaviour in the case occupants cannot choose by themselves when to turn on and off the heating system.
The use of statistics to determine the household characteristics related to energy use in buildings has proved to be useful to understand how age, household composition and occupancy influence the behaviour. As soon as more accurate data become available, in particular for energy consumption/expenditures and behaviour, through statistics it would be possible to determine the occupancy patterns to define the occupancy of a building when real information about the occupants is not available. This approach can represent a great opportunity for policy-makers and Energy Service Companies (ESCos) in case of building renovation, since the behaviour profiles can be integrated into the renovation process, resulting in a more accurate method to determine, on the one hand, the expected building performance accounting for household variation, on the other hand, the levers to be activated in order to support household in delivering the expected savings.

3.3. Applying building energy simulation and occupant behaviour modelling to support decision-making

Much research has already been devoted to combining occupant behaviour to residential building simulation. An et al. (2017) have introduced a novel stochastic modelling method of occupant behaviour into cooling load simulation, the results of which agree well with the measured data. Yu et al. (2011a; 2011b) have used basic data mining techniques (i.e. cluster analysis, classification analysis, and association rules mining) to demonstrate that improving occupant behaviour can facilitate the evaluation of building energy-saving potential. Johnson et al. (2014) have considered time use survey data as the input data to obtain Markov chain model to simulate individuals to show how an occupant interacts with the major residential energy consuming loads throughout the day. Yamaguchi et al. (2011) have also proposed a stochastic occupant behaviour model based on time use data to produce a high-temporal resolution electricity demand profile. Brandemuehl and Field (2011) have focused on the identification of the types of occupant-driven residential behaviour variations that most significantly impact the ability to predict energy consumption and peak electrical demand of a house, finding that cooling set-points and lighting power have the highest influence.

Nevertheless, although occupant behaviour simulation is increasingly recognised as a key factor in the evaluation of technologies used in building design and retrofit (Yan et al. 2015), its role to support the decision-making process is not fully exploited. Understanding the actual energy use as well as the behaviour and preferences of occupants is an essential element for the set-up and implementation of successful governance strategies and instruments. Furthermore, the engagement with occupants and the implementation of information strategies have an important role to demonstrate the potential of new social practices and to monitor the energy savings (Suárez and Fernández-Agüera 2015; Visscher et al. 2016; Feng et al. 2017).

In Italy, both residential sector renovation and the occupants' awareness raising have become increasingly important issues in the last few years. Firstly, a growing number of Italian cities has decided to revise their spatial planning tools in order to promote land preservation policies (Tondelli and Conticelli 2017) and to manage more effectively the densification and the regeneration of the built environment (Conticelli et al. 2017); the 7.13% of the national territory has already been consumed, a share that rear up to 75% in high-density urban areas (SNPA 2022), therefore the current challenge is to regenerate the built environment. Secondly, according to the national legislative decree D.Lgs. July 4th 2014 no. 102 implementing the Directive 2012/27/EU on energy efficiency, starting from 2017 the installation of meters to account energy at household level is mandatory in existing buildings with central heating system. This increase in households' freedom-to-choose is believed to be a strong incentive for occupants to save energy (Semprini et al. 2015), although it also makes urgent to adopt informative strategies towards the occupants to make the energy savings effective. Furthermore, as already discussed in Chapter 1, European Union has stressed that the Member States shall undertake an exemplary role in the energy retrofit of the public building stock in their countries, encouraging public administrations to adopt energy efficiency plans, to implement energy management systems in their buildings, and to make use of Energy Performance Contracting (EPC) and services of Energy Service Companies (ESCos).

Occupant behaviour modelling is an important tool to quantify the impact of occupant behaviour on energy saving potential. It provides estimation of the gap between expected and actual energy savings linked to the human factor. It explains the impact of rebound effect in case of building retrofit, as well as the impact of "green behaviour" (Ben and Steemers 2014) when positive behavioural changes occurs.

A building performance simulation tool has been applied by Santangelo et al. (2018) to investigate the impact of the human factor in energy consumption at building scale and to build scenarios to support decision-makers regarding design renovation strategies to apply to the public housing sector. The case study is modeled using the dynamic building simulation program DeST (Yan et al. 2008; Zhang et al. 2008). The model is adopted as well in this section to reinforce two discourses: on the one hand, the simulation results at building level are powerful tools to demonstrate that complementary approaches to reduce energy consumption are required, since physical improvements and behavioural change show different impact on energy savings that need to be addressed at the same time; on the other hand, the simulation results at dwelling scale are presented and discussed based on Santangelo et al. (2021), to provide inputs to design energy poverty strategies.

3.3.1. Basic assumptions around the model

As in previous research (Santangelo et al. 2018; Santangelo et al. 2021), a multi-family public housing building in Bologna, the capital city of Emilia-Romagna Region, is assumed as the case study to estimate the influence of three dimensions linked to occupant behavior—management of the thermostat, management of the heating system and variation of building characteristics—on energy heating consumption.

The reference building is a ten-story building (ground floor on *pilotis*) built in 1976, with five staircases and 92 housing units. Each story hosts from 6 to 11 housing units, while their sizes vary from 65m^2 for the smallest housing unit, to 116 m^2 for the largest one.

The reference building has a centralized heating system which operates for 14 hours per day during the reference period (i.e. from the 15th of October to the 15th of April, according to E climate zone), from 6 to 9 am, and from 11 am to 10 pm. Since the measured consumption refers to the 2011, the Bologna meteorological data of the whole 2011 are used for the analysis of the heating consumption. When it comes to internal gains, since the Italian average household size is 2.4 persons (ISTAT 2015), the number of people considered for each housing unit in the model is the statistical number rounded up to three people. Thermal characteristic values of main building elements have been considered as representative of the residential buildings built between '60s and '80s in Italy, particularly in the public housing sector where the greater amount of the stock is the result of the combination between precast and construction materials with poor thermal properties. Window surface is larger than the average for similar buildings and it is made by aluminium frame with single glass, resulting in a high heat-dissipating element.

Three different Occupancy Modes (OMs) have been considered. Each OM is representative of the number of hours that household spend at home with the heating system on and the thermostat at the highest preferred temperature. OM1 considers tenants setting the heating system at the preferred temperature for 14 hours per day (from 6 to 9 am and from 11 am to 10 pm), which decrease to 11 hours per day for OM2 and 8 hours per day for OM3.

Two extreme cases have been taking as a reference. In the first case, the central heating system of the reference building is turned on for 14 hours per day and occupants are not allowed to switch on/off the heating system, while they may choose the temperature set-point and the time to spend with their preferred set-point, among the 14 hours that the system is on. They choose to adopt an "energy intensive behavior", with the temperature set at 22°C in all the rooms for the maximum number of hours defined by the Occupancy Attitudes. In the second case, households decide to switch off the heating system when out from home and not using some of the rooms (e.g., bedrooms during the day), in accordance to the assigned Occupancy Mode. In addition, they adopt an "energy saving behavior" setting the temperature to 20°C when the heating system is operating, and the rooms occupied.

The two abovementioned cases have been simulated according to three different building characteristics. "No retrofit" applies when no physical intervention to the building elements is foreseen. "Limited retrofit" foresees the replacement of the single glass windows with double glass windows and the insulation of the roof. "Total retrofit" is the deepest level of retrofit considered, when all the external elements are renovated, and the building is completely retrofitted. The heat transmission values (U) considered are the minimum requirements for the renovation of the existing buildings in the municipality of Bologna, according to the regional regulation (Emilia-Romagna Region, 2015).

3.3.2. Findings at building level support the design of behavioural change campaigns

Table 3.5 shows the impact of behaviour change on heating loads in terms of heat demand and saved energy consumption for the three levels of renovation. The results reveal the importance of the retrofit to reduce energy demand. As expected, the renovation and/or replacement of existing building characteristics permit a huge reduction in heating loads and it shows a greater impact than the benefit gained from changing in occupant behaviour. Nevertheless, strategies

Table 3.5. The impact of behaviour change on energy loads. Source: author's elaboration.

	No retrofit		**Limited retrofit**		**Total retrofit**	
	Energy intensive behaviour	Energy saving behaviour	Energy intensive behaviour	Energy saving behaviour	Energy intensive behaviour	Energy saving behaviour
Energy						
Heat demand (kWh/y)	576,953	493,810	286,340	237,881	55,975	37,626
Heat demand per m^2 (kWh/ m^{2}y)	89.4	76.6	44.4	36.9	8.7	5.8
Saved energy compared to the highest energy consumption for the reference building (kWh/y)	-	83,143	290,614	339,072	520,979	539,327
Saved energy compared to the "Energy intensive behaviour" (kWh/y)	-	83,143	-	48,458	-	18,348
Saved CO_2 emissions (ton/y)	-	17	58	68	104	108

to raise awareness on energy consumption are a powerful tool to save energy particularly in the case of no retrofit of the building, when 83,143 kWh/year can be saved for the whole reference building by adopting certain behaviour changes. The findings suggest a range up to 14-33% for the impact of human factor on energy savings, depending on the simulated cases and the levels of retrofit considered. This impact increases as the retrofit level increases in terms of percentage on the total heating consumption, while the amount of saved energy due to behaviour change decreases as the retrofit level increases.

This research contributes to demonstrate the importance of integrating strategies to tackle behavioural factors to retrofit strategies to improve the energy performance of residential buildings. This section describes two divergent explorative scenarios aiming at demonstrating that complementary approaches to reduce energy consumption are required, since physical improvements and behavioural change show different impact on energy savings that need to be addressed at the same time.

The first scenario represents the hypothesis in which the municipality of Bologna and the public housing provider, respectively owner and manager of the reference building as part of the public housing stock, decide to include the case study within a regeneration programme that aims at reducing heating consumption in existing residential public buildings. Due to the lack of funding, they decide to implement a significant and long-lasting energy awareness campaign, rather than intervening on the physical elements of the building. From the content side,

it includes communication materials and organisation of events to inform on the regeneration programme; explanatory material to properly use new technologies installed and to set the temperature; education material to raise awareness on behaviour impact and how to optimise energy consumption; direct and indirect feedbacks and tips by email and regular mail. In terms of costs, it foresees a total investment of 54,000 euro for 15 years: 20,000 euro for the first year to properly design and launch the campaign; 5,000 euro once every five years to recall aim and impact of the regeneration programme; and 2,000 euro every year to support the daily activities, tackling also the household turnover in social housing dwellings where allocation is subject to the persistence of certain criteria.
The theoretical investigation on occupant behaviour simulation shows that behavioural change has a significant impact on the total amount of energy consumption. After the meters are installed, households can set their preferred temperature in a range between 18°C-22°C. They choose to set 22°C, since their energy bills are going to be calculated in a different way than before, they do not perceive the consequences of their behaviour; they simply choose to increase their comfort by choosing 1°C more than the set-point previously fixed by the public housing manager. As consequence, the building heating consumption increases, and the public housing owner, together with the provider, decides to invest on raising awareness on the need to change behaviour. By setting a lower temperature of 20°C, the building heating consumption decreases and up to 10% of the total consumption can be saved. Savings can reach the 14% when this energy saving behaviour is combined with the suitable use of the dual set-point and the heating system is off when the dwellings are empty.
The preliminary economic evaluation, taking into consideration the total investment costs for energy awareness campaign for 15 years and the saved costs both for energy and CO_2 emissions, shows a positive NPV, meaning that investing on occupant behaviour to reduce energy consumption is fully sustainable also from the economic point of view. Due to occupant behaviour change, the saved costs for energy consumption of the whole building reach more than 130,000 euro for the 15-years period considered. Moreover, the investments to support behaviour change represent the first step to achieve energy reduction and it can be easily combined with the renovation of the building when more funds are available, to maximise the benefits.
The second scenario foresees a consistent investment on building retrofit. In this hypothesis, both the owner and the manager of public housing stock decide to retrofit the whole building by insulating the external walls and roof and by replacing the windows; the thermal proprieties of the building elements are chosen in coherence with the criteria set by the Emilia-Romagna regional directive for the renovation of existing buildings (D.G.R. 967 20 luglio 2015). To implement the retrofit, an ESCo is involved and an Energy Performance Contract (EPC) is signed. Due to the considerable drop of expected energy consumption compared to the current situation, no campaign is foreseen to tackle occupant behaviour impact.

In terms of costs, it foresees a total investment of about 1.1 million euro, 50% for the replacement of windows, 45% for insulating the external walls, 5% for the roof insulation. This high retrofit level solution is expected to save more than 800,000 euro of costs for energy and CO_2 emissions in 15 years, but the savings are not enough to cover the total investment, therefore the municipality should decide either to cover a part of it, or to extend the EPC duration. However, the higher is the uncertainty related to occupant behaviour, the higher might be the payback time for renovation investments, decreasing the attractiveness for private companies to deliver such renovation.
Despite results show the global renovation is the best way to significantly decrease the heating consumption of the building, the impact of the rebound effect has proven to be relevant. The results of the study on occupant behaviour simulation show that rebound effect increases the energy spending of 17% for limited retrofit of the building and 33% for total retrofit, due to different occupant behaviour than the one simulated.
The findings suggest that, if this second scenario occurs, the heating consumption for the whole building decreases considerably. Nevertheless, the rebound effect may affect energy savings by increasing up to 1/3 the total energy consumption, resulting in difficulties to meet the investment payback period and low attractiveness of the renovation practices from private partners.

3.3.3. Findings at dwelling level support the design of energy poverty strategies

Three levels of renovation are simulated to check whether the variation among the dwelling occupancy and types of dwelling remain stable or not as the energy efficiency of the dwelling changes. Three different dwelling sizes are considered. They are located in mid stories (i.e. fourth, fifth and sixth stories) to limit the influences of the heating loads due to the poor thermal properties of floor and roof. Housing unit A is the smallest among the considered ones, the total net size is 65 m^2 with one bedroom, kitchen, living room, bathroom and corridor. It faces north and east at the building corner, with two external walls, and one of the internal walls next to the building staircase. The Occupancy Mode varies among the different stories, therefore OM1 is assigned to housing unit A at story 6, OM2 at story 5, while OM3 at story 4 (Figure 3.2). Housing unit B is located on the opposite side of the staircase, it is 79 m^2 large and it has two bedrooms, kitchen, living room, bathroom and corridor. The kitchen and one of the bedrooms face east, while the living room and the other bedroom face west. OM1 is allocated to housing unit B at story 5, OM2 at story 4, and OM2 at story 6. The last dwelling considered, housing unit C, has a surface of 99 m^2, one more bathroom and bedroom than housing unit B. It is an internal unit with only two external walls facing east and west, while internal walls border on the one hand the staircase, on the other hand a specular housing unit.
Table 3.6 shows the heating load simulation results according to the different housing units and different Occupancy Modes, also taking into consideration the building retrofit level. Similarly to what resulted from the investigation at building

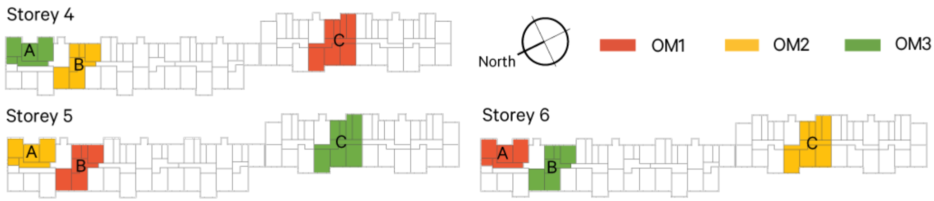

Figure 3.2. Housing units and Occupancy Mode distribution. Source: author's elaboration

scale (Santangelo et al. 2018), the analysis at dwelling scale, as already presented in Santangelo et al. (2021), confirms that the more the dwelling is energy efficient, the greater is the share of the energy consumption that occupant behavior can affect, up to 52% of energy reduction for housing unit B with Occupancy Mode OM3 (i.e. "back home in the afternoon" with the heating system at the maximum preferred temperature for 8h/day) in case of total retrofit. However, the no retrofit scenario is the one which shows the highest potential for occupants to decrease the dwelling heating load in absolute terms, up to 818 kWh/year of reduction for housing unit A with OM3 by adopting an energy saver behavior, with full control and dual set-point. As expected, results also show that the higher the exposure to external conditions due to the location at the building corner, the higher is the heating load per square meter yearly. In fact, housing unit A can require more energy than larger dwellings as housing units B and C, with the same building component thermal proprieties, but located in a more favorable position within the building. In case of limited retrofit, the simulated heating load for housing unit A is 2.2 times higher than the one for housing unit B, and 2.6 times more than the one for housing unit C.
The Occupancy Modes play also a role in the definition of the dwelling energy demand. Regardless of the retrofit level of the dwelling, there is a common tendency to an energy demand decrease as the number of hours the heating system is operating decreases. Taking into account the Case 2 where households adopt an energy saver behavior compared to Case 1, results show that, in case of no retrofit occurs, the energy reduction is in the range of 11-14% for OM1, 12-15% for OM2 and 17-21% for OM3, depending on the housing unit considered. Energy savings increase as the energy efficiency of dwellings increases. Therefore, they are in the range of 15-23% for OM1, 16-24% for OM2 and 23-29% for OM3 when the limited retrofit occurs; and 31-51% for OM1, 35-51% for OM2 and 39-52% for OM3 when the dwellings are totally retrofitted. However, for all the three retrofit levels and all the dwellings considered, lower time spent at home with the heating system on generates higher energy savings.
When it comes to the rebound effect identification, the investigation at dwelling level shows that it can be even higher than the one identified with heating load simulations at building level as presented in Santangelo et al. (2018). In fact, if occupants just decide to change the thermostat from 20°C in day-zone and 18°C in bedrooms when occupied to 22°C in all rooms for the maximum working hours of the heating system (i.e., from energy saving behaviour to energy intensive one),

Table 3.6. Heating load simulations related to types of dwelling and Occupancy Modes (OMs) for the three levels of renovations.

	Energy intensive behaviour		Energy saving behaviour					
			OM1 (14h)		OM2 (11h)		OM3 (8h)	
	kWh/y	kWh/m2y	kWh/y	kWh/m2y	kWh/y	kWh/m2y	kWh/y	kWh/m2y
NO RETROFIT			**- 11-14%**		**- 12-15%**		**- 17-21%**	
HOUSING UNIT A	4,244	65.3	3,779	58.1	3,748	57.7	3,426	52.7
HOUSING UNIT B	3,667	46.4	3,167	40.1	3,120	39.5	2,891	36.6
HOUSING UNIT C	4,709	47.6	4,184	42.3	4,157	42.0	3,896	39.4
LIMITED RETROFIT			**- 15-23%**		**- 16-24%**		**- 23-29%**	
HOUSING UNIT A	2,241	34.5	1,912	29.4	1,886	29.0	1,715	26.4
HOUSING UNIT B	1,036	13.1	794	10.1	786	9.9	739	9.4
HOUSING UNIT C	1,558	15.7	1,252	12.6	1,213	12.3	1,135	11.5
TOTAL RETROFIT			**- 31-51%**		**- 35-51%**		**- 39-52%**	
HOUSING UNIT A	356	5.5	247	3.8	232	3.6	217	3.3
HOUSING UNIT B	305	3.9	148	1.9	148	1.9	146	1.8
HOUSING UNIT C	311	3.1	208	2.1	200	2.0	178	1.8

then the consumption increases and the rebound effect reaches up to 23%, 29% and 27%, respectively for limited retrofit of housing unit A, B and C. When the total retrofit occurs, the rebound effect can increase further up to 39%, 52% and 43%, respectively for housing unit A, B and C, in comparison with the expected consumption after the renovation.

Despite these results are not surprising, they deserve to be outlined since they show variance in the energy saving potential of different households living in different dwellings. Therefore, it is of key importance to understand household's saving potential in relation to the dwelling characteristics they lived in, and to avoid to "blame the victim" (Stevenson and Leaman 2010), especially in the public housing sector where the random allocation of dwellings generates inequalities in energy costs and energy poverty conditions. Due to the fact that public housing is allocated according to the income level and the household size, but not the housing unit characteristics, and the social rent is calculated mainly according to the income rather than the energy efficiency of the dwellings, inequalities among low-income families might be exacerbated. Therefore, strategies addressing energy poverty should take into account the challenges linked to the allocation system and the rent calculation system.

3.4. Making the relevance of consumer behaviour explicit: a multi-criteria analysis

Researchers have started questioning the effectiveness of retrofitting policies, since they are mainly based on theoretical assumptions (Galvin 2014) and do not accommodate user energy practices (Gram-Hanssen et al. 2018). In order to achieve real energy reduction, policy instruments need to include considerations on the actual use of buildings, rather than the theoretical consumption (Visscher et al. 2016). Nowadays policy-makers are struggling to find mechanisms and resources to increase the renovation rate of their building stock. In the last decade, they have been failing in leading the renovation process on public buildings, while the property fragmentation represents a limit to the implementation of renovation strategies in the private housing sector.

Some past studies have shown multi-criteria analysis as a powerful tool to identify priorities for energy efficiency measures. A study conducted in Dortmund analysing energy efficiency measures in public buildings (März et al. 2011) has shown as Multi-Criteria Analysis (MCA) can simplify complex situations when it comes to allow decision-makers to include a full range of social, environmental, technical and economic criteria to their decisions on measures to be implemented to unlock the energy saving potential of buildings. The results highlighted which energy efficiency measures should be implemented to achieve the greatest benefit for the city, resulting in a ranking list of measures and recommended solutions. A similar research has been performed in Italy by considering the Sustainable Energy Action Plan of the city of Melzo (Dall'O' et al. 2013). Results have demonstrated how considering only the economic approach to make decisions on the renovation of buildings leads to results that do not take into consideration one of the most important goals of cities – to increase the sustainability of the whole community. However, in both studies, the considered renovation strategies have not explicitly incorporated initiatives addressing user behaviour among the recommended solutions to be implemented neither prior, nor after renovation. Without considering energy behaviour has a key factor for the success of strategies addressing buildings renovation, the expected energy savings have been demonstrated to be misleading, and the impact of such energy reduction measures overestimated.

Based on a study published by Santangelo and Tondelli (2018), this section presents a methodology based on multi-criteria assessment of different strategies by applying the Analytic Hierarchy Process (AHP), aiming at providing support to policy-makers for their decisions concerning the reduction of energy consumption in buildings. The methodology has been designed to explicitly incorporate the impact of user behaviour into the assessment of planning strategies and renovation measures. Previous research is presented, together with the adopted methodology, the main steps of the AHP, and the selected measures, criteria and scenarios. The alternatives that are more dependent from behaviour are identified, and the way to tackle this uncertainty in the pairwise comparisons is presented. The findings are then discussed in terms of possible steps to unlock the energy saving potential of buildings.

To support decision-makers to design effective energy efficiency renovation policies, a methodology based on the application of the Analytic Hierarchy Process (AHP) is presented. AHP is a decision support technique based on pairwise comparisons and on the judgements of experts to derive priority scales. The comparisons are made using a scale of absolute judgements that represents, how much more, one element dominates another with respect to a given attribute. Through these scales, is possible to measure intangibles in relative terms. The judgements may be inconsistent, therefore, consistency should be checked and kept within certain values (Saaty 1990; Saaty 2008). To generate priorities to support decisions, four main steps have to be followed: i) to define the problem, and to set the goal; ii) to structure the decision hierarchy from the top (the overall objective), through the intermediate level (criteria), to the lowest level represented by the alternatives (measures); iii) to build pairwise comparison matrices and undertake a consistency test; iv) to estimate the relative weighs of the components of each level. AHP scale considered is as follows: 1 for equal importance; 3 for moderate importance; 5 for strong importance; 7 for very strong importance; 9 for extreme importance; pair values are used for priorities in-between the odd ones.

The methodology described as follows aims to demonstrate that the measures tackling user behaviour are the most urgent to be implemented and, therefore, they should be on the top of the priority list when it comes to design effective renovation strategies of the housing stock. Thus, energy behaviour of occupants needs to be embedded in renovation policies, in order to reduce the gap between expected and actual energy consumption, to raise awareness on the individual impact on the energy consumption and to build sustainable communities. A sensitivity analysis is performed to design different scenarios based on the allocation of priorities among different criteria. The scenarios are intended as multiple ways to achieve the above-mentioned goal.

The overall objective considered as the goal of the AHP application, is to lower energy consumption in housing sector by selecting the measures that more than others can lead to an effective implementation of the energy renovation strategies.

Among the numerous criteria and indicators that are normally used in environmental assessment of buildings, four criteria have been taken into consideration for the aim of this study. The *environmental criterion* is the one aiming at maximising the energy and CO_2 reduction, no matter the economic,

social and practicable feasibility of implementing the renovation alternatives. The *economic criterion* aims at maximising the revenues and/ or minimising the loss, thus takes into consideration the cost-effectiveness of measures. The *social criterion* is the one recognising the importance of social and cultural values, and support inclusion of these values in the selection of energy renovation measures. The last criterion considered is the *practicability* of such energy efficiency measures, evaluating how easy and free from operational barriers is the applicability of the foreseen measures.
As results of literature and case studies review, taking as a reference the renovation practices of Italian residential building stock (Semprini et al. 2015; Santangelo et al. 2018), seven packages of measures – M(1) to M(7) – have been identified as potential alternatives to improve the energy performance of the housing stock (Table 3.7).
These measures have been clustered according to their levels of dependency from the occupant behaviour. M(1) and M(2) are the two alternatives strongly dependent on occupant behaviour, since they are designed to address directly the behaviour change and the households awareness of their impact on energy consumption. M(3), M(4) and M(5) are dependent to a certain degree on occupant behaviour. In fact, whether the heating system, the home appliances and the windows are efficient or not, it will still be the occupant who decides how to use them, introducing a level of uncertainty of such measures to increase the energy efficiency of housing buildings. On the contrary, M(6) and M(7) have been clustered as non-dependent on behaviour, since they represent the alternatives that more than others are able to reach the target of energy efficiency they are designed for, with limited influence of occupant behaviour.
The structure of the hierarchy framework is based on three main levels. The first level represents the goal of the analysis. The second level is composed by multiple criteria. The last level is made by the alternative choices or measures.
The results report the application of AHP according to the hierarchy of goal, criteria (i.e., environmental, economic, social and practicable) and the measures as described above. The following part describes the scenarios selected and how the criteria are combined among them to define the five scenarios.
The consistency test is one of the essential features of the AHP method which aims to eliminate the possible inconsistency revealed in the criteria weights through the computation of consistency level of each matrix. The consistency ratio (CR) is used to determine and justify the inconsistency in the pairwise comparison (Saaty 1990). The acceptable CR values is assumed 0.10 for matrix larger than 4x4. All the CR values of the matrixes considered are below this limit, therefore, the weight results can be assumed as valid and consistent.
The results from the environmental criterion decision matrix are presented, prioritised and ranked in Table 3.8. The priorities have been assigned by the author and fine-tuned by involving a restrict panel of scholars. Results already available in literature have been used to assess the measures M(1)-M(7) in pairwise comparisons. In order to highlight the medium-dependency level of

Table 3.7. List of measures and link to behaviour. Source: author's elaboration.

No. of MEASURES and type	LINK TO BEHAVIOUR
M(1) - Indirect feedback	High
M(2) - Direct feedback/ smart meters	High
M(3) - Replacement of the heating system	Medium
M(4) - Replacement of home appliances/ lights	Medium
M(5) - Replacement of windows	Medium
M(6) - Insulation of building envelope	Low/ None
M(7) - Renewable energy systems	Low/ None

M(3), M(4) and M(5) from behaviour, the preference of such measures pairwise compared to M(1) and M(2) have been lowered (i.e. two points decreased in the scale of preference). This assumption has been made to incorporate the somehow dependency on behaviour of such measures. Selecting M(3), M(4) and M(5) without taking into consideration that they are influenced from user behaviour can lead to overestimate the environmental benefit of such measures.

Tables 3.9-3.11 present the results from pairwise comparisons taking into consideration respectively the economic, social and practicable criteria. Each table shows the priority of selected measures according to the results of the decision matrix, and the ranking of the alternatives when each criterion is considered alone, in absolute terms.

Figure 3.3 shows the priority trend of each criterion. "M(1) – Indirect feedback" and "M(2) - Direct feedback/ smart meters" are the top alternatives considering three out of four criteria, while implementing "M(7) - Renewable energy systems" has the highest priority when the environmental criterion is considered. Beside these three solutions, "M(4) - Replacement of home appliances/ lights" is the measure showing most significant changes among the criteria.

In order to include all the main alternative decisions that policy-makers might face to reach the overall objective of lowering energy consumption in housing sector, a sensitivity analysis has been performed to define five possible scenarios that includes different combination of the selected criteria.

The weights assigned for each scenario are presented in Table 3.12. The neutral scenario foresees a decision made by equally evaluate the four criteria. The other scenarios are designed to make one criterion prevail, with a double weight with respect to the other three criteria.

The results of the sensitivity analysis are presented in Table 3.13 The rows represent the seven measures, while the five main columns show both the priority and the ranking of each scenario. Recommendations on which measures should be selected first are drawn by taking into consideration the results of each ranking list. The traffic light colours from green to red show the priority of recommended solutions. The evidence of how behaviour is embedded into the measures with the highest scores is presented in Figure 3.4.

Table 3.8. Pairwise comparison for environmental criterion. Consistency Ratio CR = 0.09. Source: author's elaboration.

ENVIRONMENTAL CRITERION									
DECISION MATRIX	M(1)	M(2)	M(3)	M(4)	M(5)	M(6)	M(7)	PRIORITY	RANKING
M(1)	1	0.33	0.33	0.33	0.33	0.14	0.11	2.6%	7
M(2)	3.00	1	0.33	0.33	0.33	0.14	0.11	3.6%	6
M(3)	3.00	3.00	1	3.00	0.33	0.20	0.14	7.6%	4
M(4)	3.00	3.00	0.33	1	0.33	0.20	0.20	5.8%	5
M(5)	3.00	3.00	3.00	3.00	1	0.20	0.14	10.5%	3
M(6)	7.00	7.00	5.00	5.00	5.00	1	0.33	26.5%	2
M(7)	9.00	9.00	7.00	5.00	7.00	3.00	1	43.4%	1

Table 3.9. Pairwise comparison for economic criterion. Consistency Ratio CR = 0.05. Source: author's elaboration.

ECONOMIC CRITERION									
DECISION MATRIX	M(1)	M(2)	M(3)	M(4)	M(5)	M(6)	M(7)	PRIORITY	RANKING
M(1)	1	3.00	5.00	3.00	7.00	9.00	7.00	40.5%	1
M(2)	0.33	1	1.00	3.00	5.00	7.00	7.00	21.7%	2
M(3)	0.20	1.00	1	1.00	1.00	5.00	5.00	12.3%	4
M(4)	0.33	0.33	1.00	1	3.00	5.00	5.00	12.9%	3
M(5)	0.14	0.20	1.00	0.33	1	3.00	3.00	6.9%	5
M(6)	0.11	0.14	0.20	0.20	0.33	1	1.00	2.8%	7
M(7)	0.14	0.14	0.20	0.20	0.33	1.00	1	3.0%	6

Table 3.10. Pairwise comparison for social criterion. Consistency Ratio CR = 0.03. Source: author's elaboration.

SOCIAL CRITERION									
DECISION MATRIX	M(1)	M(2)	M(3)	M(4)	M(5)	M(6)	M(7)	PRIORITY	RANKING
M(1)	1	3.00	5.00	5.00	5.00	7.00	5.00	41.5%	1
M(2)	0.33	1	3.00	3.00	3.00	5.00	3.00	29.4%	2
M(3)	0.20	0.33	1	1.00	1.00	1.00	1.00	6.0%	3
M(4)	0.20	0.33	1.00	1	3.00	3.00	1.00	6.0%	3
M(5)	0.20	0.33	1.00	0.33	1	1.00	1.00	6.0%	3
M(6)	0.14	0.20	1.00	0.33	1.00	1	0.33	5.5%	6
M(7)	0.20	0.33	1.00	1.00	1.00	3.00	1	5.5%	6

Table 3.11. Pairwise comparison for social criterion. Consistency Ratio CR = 0.06. Source: author's elaboration.

PRACTICABLE CRITERION									
DECISION MATRIX	M(1)	M(2)	M(3)	M(4)	M(5)	M(6)	M(7)	PRIORITY	RANKING
M(1)	1	3.00	5.00	3.00	5.00	9.00	7.00	38.9%	1
M(2)	0.33	1	3.00	1.00	5.00	5.00	5.00	20.0%	2
M(3)	0.20	0.33	1	0.33	1.00	5.00	3.00	8.8%	4
M(4)	0.33	1.00	3.00	1	3.00	5.00	5.00	18.0%	3
M(5)	0.20	0.20	1.00	0.33	1	3.00	3.00	7.4%	5
M(6)	0.11	0.20	0.20	0.20	0.33	1	3.00	3.9%	6
M(7)	0.14	0.20	0.33	0.20	0.33	0.33	1	3.1%	7

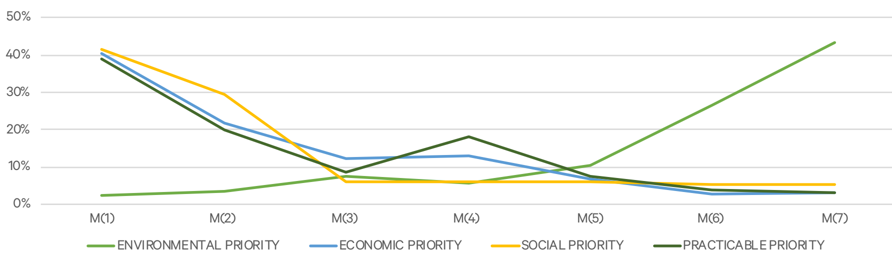

Figure 3.3. Criteria priority. Source: author's elaboration.

Results show that "M(1) - Indirect feedback" and "M(2) - Direct feedback/ smart meters", the two measures that more than the other considered rely on user behaviour, have resulted to be the top alternatives by three out of four criteria. Afterwards, a sensitivity analysis has been performed to define five possible scenarios that includes different combination of the selected criteria. The aim has been to include all the main alternative decisions that policy-makers might face to reach the reduction of energy consumption by renovating the housing stock. The analysis has confirmed the urgency and convenience to implement the first two measures prior to the other alternatives.

This research has contributed to highlight the central role of household behaviour and daily practices to lower energy consumption when it comes to renovation of existing housing buildings. Nevertheless, the research embeds also some limitations. First of all, the decisions on the scores of pairwise comparisons have been made directly by the author and fine-tuned by involving a restrict panel of scholars. Although they result from the evidence of collaborations with public authorities, to enhance the robustness of the results, it might be suggested to design a participatory process to directly involve experts in decisions, or to deliver a survey to gather stakeholders' feedback on the priorities. Secondly, to the extent of the study, informational feedback – both direct and indirect – has

Table 3.12. Weights assumption for sensitivity analysis.

	ENVIRONMENTAL CRITERION	ECONOMIC CRITERION	SOCIAL CRITERION	PRACTICABLE CRITERION
NEUTRAL SCENARIO	25%	25%	25%	25%
ENVIRONMENTAL SCENARIO	40%	20%	20%	20%
ECONOMIC SCENARIO	20%	40%	20%	20%
SOCIAL SCENARIO	20%	20%	40%	20%
PRACTICABLE SCENARIO	20%	20%	20%	40%

Table 3.13. Results from sensitivity analysis and ranking of recommended solutions (P: priority, R: ranking). Source: author's elaboration.

RECOM-MENDED SOLUTIONS	NEUTRAL SCENARIO		ENVIRONMENTAL SCENARIO		ECONOMIC SCENARIO		SOCIAL SCENARIO		PRACTICABLE SCENARIO	
	P	R	P	R	P	R	P	R	P	R
M(1)	30.9%	1	25.2%	1	32.8%	1	33.0%	1	32.5%	1
M(2)	18.7%	2	15.7%	3	19.3%	2	20.8%	2	18.9%	2
M(3)	8.7%	5	8.5%	6	9.4%	5	8.1%	6	8.7%	5
M(4)	10.7%	4	9.7%	5	11.1%	4	9.7%	4	12.1%	3
M(5)	7.7%	6	8.3%	7	7.5%	6	7.4%	7	7.6%	7
M(6)	9.7%	7	13.0%	4	8.3%	7	8.8%	5	8.5%	6
M(7)	13.8%	3	19.7%	2	11.6%	3	12.1%	3	11.6%	4

been considered to lead to behaviour change due to rational behaviour. However, this approach has been criticised for relying on assumptions of consumers as guided by economically rationally decisions, while in practice it is not the case. Although the limits of this kind of strategy, informing the users still represent an important element in the implementation of structural strategies intended to increase the energy efficiency of buildings.

Two main policy recommendations can be drawn. On the one hand, even if the increasing availability of data on household energy consumption and indoor comfort levels gives more possibilities of providing tailored feedback to occupants, there is a limited evidence of post-occupancy evaluation studies in existing literature. Thus, the measures proposed in this research, with a high dependency on behaviour, are intended as complementary to the others, and the first to implement to raise awareness and drive behaviour towards more energy sustainable practices, but they certainly cannot reach the goal if implemented alone. Information, awareness campaigns, feedback and other informative policy

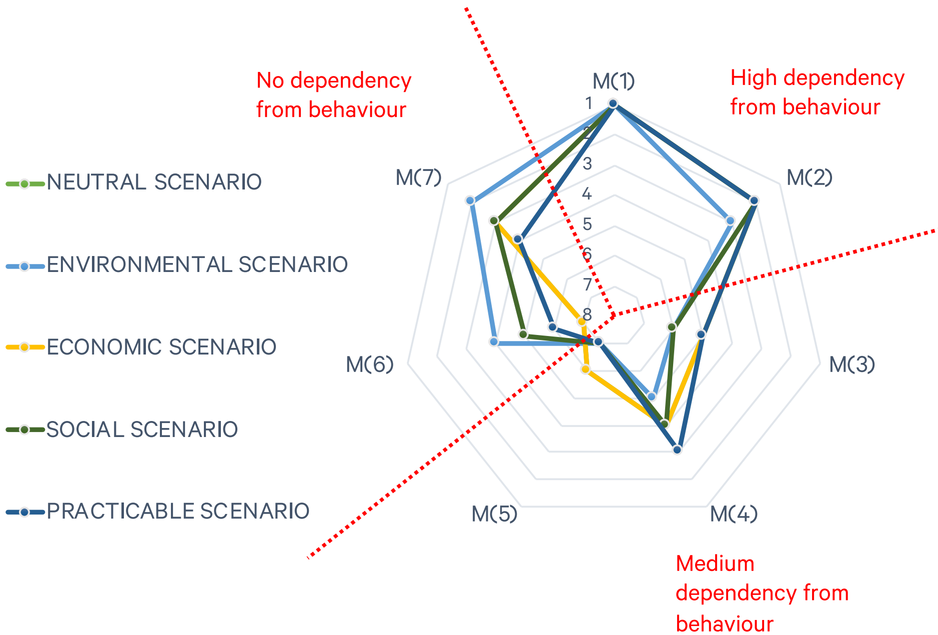

Figure 3.4. Scenario analysis and degree of relevance of energy behaviour. The neutral scenario overlappes with the economic scenario. Source: author's elaboration.

instruments should be integrated by other measures addressing the physical renovation. On the other hand, public authorities are seeking for services, rather than products to increase the renovation rate of the housing stock. Technologies should be only one aspects of a complex system where spatial organization, consumer behaviour and technologies interact with each other, determining the actual and future pattern of energy consumption (Papa et al. 2016). Better integrated complementary approaches to both the technical and social energy transitions are required.

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››› 4.
Embedding strategies tackling consumer behaviour into existing policy instruments. The Italian public housing sector as a case study

4.1. Italian public housing characteristics

4.1.1. Size, tenure and target group

In the European context, Italy emerges as one of the Countries where social housing is less developed and, more generally, public expenditure for housing is lower: only 0.1% of total social expenditure is devoted to housing, less than 1% of the total expenditure of EU Member States (Eurostat 2018). Less than 4% of all households live in social housing dwellings, with the public sector having almost the exclusive role in providing social housing. Therefore, the Italian social housing can be almost totally identified with public housing.

Today, Italian public housing is managed by municipalities, either directly or through special public housing providers. Renting is by far the most prevalent tenure (i.e. almost 95% of the total dwellings) (NOMISMA 2016). However, assisted home-ownership has always been part of public housing schemes through various forms of leasing contracts (Baldini and Poggio 2014). At the end of 2013, the total available stock accounted for about 805,000 housing units, however, only 86% was properly allocated, 5% less than 2004, resulting in an increasing share both in the number of squatters and in the number of vacant dwellings due to insufficient maintenance condition. 55% of public housing tenants pay less than 100 euro per month, while the rate of households paying a rent higher than 300 euro is only about 7% (NOMISMA 2016). 45% of the total public housing stock is located in the 12 biggest urban areas, where the higher housing demand is concentrated.

The Italian model of housing policy is defined as "targeted residual" (Czischke and Pittini 2007), aimed at providing decent housing only to the households most in needs. Access to public housing is related to the income level, and the selection criteria for economic and social needs are tight. In practice, however, targeting is fair but not fully effective (Baldini and Poggio 2012). The turnover rate of social tenants is extremely low, and most of the occupants tend to remain in public housing for their entire lives, regardless improvements in their economic and social conditions. This propensity for stability, together with the reduction in the flow of new dwellings, explains the progressive ageing of occupants. Elderly people, in fact, are the main beneficiaries, with more than 44% of household heads having 65 years old or more, while the share reaches 28% for those having 75 years old or more (NOMISMA 2016). Although the tight eligibility criteria, about 650,000 households across the whole Country are subscribed to the waiting

list to access to the public housing sector (Federcasa 2015). Interestingly, public housing tenants and households in the waiting list have opposite household characteristics in terms of citizenship: while about 12% of families living in social housing stock are foreign, they are 57% of the total households meeting the allocation criteria and waiting for a public dwelling.
Although housing needs have constantly increased, both in terms of affordability and quality of the housing stock, public housing sector has been continuing to shrink since the 1990s. However, the limited dimensions of public housing supply are not only due to progressively reduction of public investments. Privatization plans were presented as a way to finance the new stock and the refurbishment of the existing one. In reality, dwellings have been sold far below their market value and each new dwelling needs 4 times more resources than the earnings from the sails (Federcasa 2015). What characterises the sector is the constant tendency of Italian governments to privatise public dwellings, and to promote the ownership over renting. To some extent, many households have been forced to become home-owners as a way of getting a secure and affordable dwelling (Baldini and Poggio 2012).
Over the last decades, important changes have also taken place in the institutional framework of public housing. Competences in this area were transferred from the state to the regional governments in the early 2000s, but the funding of public housing has emerged as a major unresolved issue. The large-scale public housing schemes developed after World War II were funded by dedicated compulsory social contributions. This scheme (e.g. GESCAL) was abolished in 1998. As a result, there is no longer an automatic, stable financing mechanism dedicated to public housing at any level of government national, regional, or local. Transfers from the State to public housing agencies have been cut to almost zero, and funds from the regions have been severely reduced.
The public housing sector is therefore affected by several structural issues. The first is certainly the aforementioned lack of constant resources to be used to manage, maintain and refurbish the existing stock, not to mention the realisation of new housing stock. Cuts in public investments cumulate with other financial issues. It should be stressed that the traditional rent-setting model raises financial sustainability issues. It operates by setting a rent to cover costs, to later discount it according to the tenants' income. This model is not sustainable without a constant and consistent flux of resources to cover the expenditures and loss (Poggio and Boreiko 2017).

4.1.2. Energy efficiency of the housing stock and urban regeneration

As already pointed out, to the aim of this investigation, building energy renovation of public housing stock is believed to be a key opportunity to roll-out a comprehensive urban regeneration strategy with the aim of tackling energy poverty, boosting social cohesion and triggering local jobs. The active involvement of private actors is expected to activate the physical improvement of the built environment, but also to empower citizens to boost the effectiveness of the urban regeneration actions, where the local authorities hold the role of public directors, rather than actuators.

Going back to the 1980s, public housing regeneration strategies in Western Countries were characterised by severe limitations. Scholars across Europe have noted that regeneration programmes of the 1980s emphasised physical renovation over the development process of empowering local people to achieve real and lasting benefits for themselves or their communities. Communities were considered the place for fragmented and discontinuous activities, rather than active partners of the process (Hoatson and Grace 2002). By the mid-1990s experience led to new thinking that successful regeneration could not rely on one strategy, but needs a holistic approach applying a range of strategies (Hoatson and Grace 2002).

A certain number of planning instruments have been put in place also in Italy at national and regional level since the 1990s, to renovate the housing stock and to promote urban regeneration: PRU (Programs of Urban Renewal) targeted to public housing complexes, PRIU (Urban Regeneration Programs) to regenerate build-up areas as well as brownfields, PRUSST (Urban Regeneration Programs and Sustainable Development Planning), Contratti di Quartiere I and II. However, the results have been criticised by many scholars, due to the preference for the technical and architectural approach over the planning of interventions through participatory process (Tosi and Cremaschi 2001; Bronzini 2014). More recently, a series of housing policies has been promoted, namely Housing Plan 2008 and 2014, including also considerations on the existing public housing stock. However, they have always been targeted more to the private owners, rather than to the public housing providers. Even the taxation of public housing organizations has been less favourable than the one applied to home-owners and private landlords: about 30% of the rents – which are the main revenue of the public housing providers – is due in taxes (Poggio and Boreiko 2017).

Nowadays, housing and urban regeneration are important policy fields for Italian regional and local authorities. Regeneration has moved beyond 'bricks and mortar' approaches and now often involves social and economic initiatives. The government, however, is increasingly retreating from direct involvement in housing and urban issues and in many cases no longer has the power or the resources to determine the outcomes of decision-making processes. As a consequence, more and different actors and resources are needed to deliver housing and urban regeneration policies (van Bortel 2011; Copiello 2015).

When it comes to public housing neighbourhoods, they are generally located in peripheral areas of the city, where they experience lack of maintenance and embed high risk of social exclusion. Public-private partnership approaches may overcome obstacles such as lack of funding and lack of entrepreneurial ability of public housing providers, where improving energy efficiency of buildings is recognized as a driver of feasibility in order to involve private partners (Copiello 2015). The Italian Residential housing sector has shown a remarkable energy performance improvement, particularly since the early nineties when the first national law on energy efficiency in buildings had been enacted (i.e. law 10/91). When it comes to the energy efficiency renovation rate, it has been positive but negligible, namely 0.5% as annual average. Nevertheless, the potential for improving building energy performance is still substantial, particularly in the field of social housing (Copiello 2015). Today, the Italian housing stock is generally characterised by increasing ageing and poor energy efficiency. About 65% of the total dwellings belong to one of the three lowest energy class (i.e. E, F, G classes) (Lodi Rizzini 2013). About 500,000 public dwellings belong to the three lowest energy class, where households spend more than 10% of their income on the energy costs (Federcasa 2015).

A focus on the City of Bologna
As part of the Sustainable Energy Action Plan (Piano D'azione per l'Energia Sostenibile - PAES) and of the collaboration between the public and private sectors, the Municipality of Bologna has been working for some years on the energy efficiency programme of the public housing called Rig.ener.a, which has set the goal of energy renovation of public housing and of the activation of private resources for the implementation of the strategies for the resilience of the city. Divided into three sections, the overall strategy seeks to realise energy efficiency interventions in 23 buildings owned by the Municipality of Bologna, accounting for 954 accommodations in total, out of about 12,000 dwellings mostly located out from the city centre, in peripheral areas.
Of the approximately 20,000 housing units owned by all the municipalities part of the Bologna metropolitan area, in 2013 only about 10% had an energy certificate. Among them, 90% resulted to have an average energy performance index of 219 kWh/m^2 per year, resulting in the last energy class (i.e. G energy class). These data, even if partial, can be assumed as representative of the high energy demand not only of the public housing stock, but of the residential sector as a whole, considering that in the Bologna metropolitan area more than 60% of residential buildings was built between the 1945 and 1990, over 300,000 housing units in total (Proli et al. 2016).

4.1.3. Housing quality and (in)equality of the regeneration process
Equality and quality are two of the elements that qualify urban regeneration interventions. This sub-section aims to investigate, on the one hand, the issue of equality on a micro scale, taking into account the social rent; on the other hand, housing quality on a macro scale, considering the relationship between the retrofit interventions on the buildings and the public space next to them.
In Italy the regulation on the public housing rent is a regional subject. In Emilia-Romagna, for example, the discipline that specifies the requirements for access and stay to public accommodation has recently been changed (Regione Emilia-Romagna 2015). An "objective rent" is calculated for every dwelling taking into account the physical dwelling and building characteristics, the location, on the basis of the discipline for the determination of the "canone concordato" (agreed rent), which applies to the private rental market. The public housing rent should therefore represent a percentage of the "canone concordato" that varies according to the certified household income (i.e. ISEE calculation). Different groups of users are identified on the basis of income level, and each group results to have a different rent calculation as follows:

- *protection group* for the less advantaged tenants, for which the maximum incidence of the rent is defined based on the income, regardless the value of the dwelling;
- *access group* for households outside the protection group, with a value per square meter of the accommodation fixed by the Municipality within the minimum and maximum limits set by the Region;
- *permanence group*, with value per square meter duplicated or tripled with respect to the access group;
- *exit group*, referred to the households with an economic condition such that they cannot stay longer in public housing. They have a limited time to stay, and the rent is calculated according to free market fares and should be higher than the one for the permanence group, within the limits set by the Region.

The calculation methodology illustrated above is aimed to guarantee the observance of adequate levels of horizontal equality (i.e. in terms of economic condition, rent, equal accommodation characteristics) and of vertical equality (i.e. increased rent as the income increases), requirements that are often dissatisfied according to the rent calculation criteria applied so far according to the previous regulation (Tondani, 2006), only based on the income levels. Among the innovative features, the new discipline recognises the possibility of taking into account the energy efficiency of housing units. However, this does not represent an obligation, leaving unresolved the random results of the allocation system typical of the public housing system. In fact, housing is allocated on the basis of availability and size in relation to the household composition. Consequently, while the free residential market is able to manage the differences in energy consumption of the building stock, the allocation of public housing is effected by the risk of inequality when it comes to incorporate energy considerations into rent calculation (Proli et al. 2016). Moreover, income level and housing needs being equal, households living in energy efficient dwellings will result to have lower energy expenditures than peers living in old inefficient dwellings, with a consequent disparity in energy poverty conditions and both horizontal and vertical inequality (Santangelo and Tondelli 2017a).

Liveability is also an important issue in neighbourhoods regeneration. The quality and safety of public space and housing have been important pillars of urban policies and neighbourhood regeneration. Indeed, place-based issues, which are specific to some areas or perhaps even to a certain type of neighbourhood, may require a targeted approach. However, the current Italian approach can be defined as asset-based, rather than place-based. Interventions are focused on the building physical components of buildings and on the technological system, rather than targeted on the neighbourhood characteristics and needs. The overconfidence in technology, and the will to reduce the maintenance costs, have led public institutions to promote any energy intervention on technological components and building elements, without taking into account the role of people leaving there in actually reducing the energy consumption.

4.2. The interrelation among actors and the emerging role of tenants

As already reported, the European context is characterised by a wide variation in national housing systems and urban regeneration practices, variation caused by differences in institutional and policy contexts, the diversity of actors involved and resources available to implement both housing policies and regeneration strategies.
Across Europe social housing is a combination of public housing stock and a range of voluntary or non-profit associations and foundations, public or private non-profit companies, cooperative organizations and private investors. Besides providing solutions to low income people in housing needs, the purpose of social housing varies from country to country and from time to time, but broadly the suppliers can be required to contribute to neighbourhood renewal and environmental improvements. There is an increasing emphasis on mixed tenure and mixed income communities in order to avoid the social housing ghettos which often typified social housing provision in the past. Indeed, nowadays social housing may also have wider objectives including promoting mixed tenure communities, ensuring social mix in urban areas and contributing to social, economic and environmental objectives. Efforts are also being made to introduce a greater mix in the existing stock and to use public assets more effectively. The potential for public/private partnership is being explored in several Countries.
For the sustainability of the social housing sector, there is a growing recognition of the need for additional provision, better maintenance and improvement, regeneration and a wider range of services. However, the identification of additional streams of funding remains a challenge. The majority of investment schemes involve either using existing assets more effectively, selling property on the market, or mechanisms by which land values can be used to cross-subsidise development. This process is carried out by the decentralisation of housing policy in most EU Member States, which has changed the relationship between the State and social housing providers (Czischke and Pittini 2007). Indeed, from hierarchical control and standardised production of social housing, the sector has moved towards more contractual relationships between the public authorities and the increasingly independent providers.
The institutional framework concerning housing and urban regeneration is nowadays more fragmented, involving more actors than in the past, both for-profit and non-profit. The role of the government is becoming less prominent, while the influence of market actors and civil society organisations is increasing. By building on existing findings from previous research investigating the role of the third sector and governance networks particularly in the housing sector (Brandsen et al. 2005; van Bortel 2011), an overview of actors involved in the regeneration process of public housing sector has been developed. Five main categories of actors can be identified (Santangelo and Tondelli 2017b): the public authority, responsible for housing policies and strategies to tackle housing needs;

Table 4.1. Actors involved in regeneration of social housing provision according to categories and conceptual borderlines. Source: author's elaboration, adapted from van Bortel (2011).

Categories	Formal/ informal organisations	Profit/non-profit actors	Public/private sectors	Services of general interest
Public authority	Formal	Non-profit	Public	Yes
Social housing provider	Formal	Non-profit	Public	Yes
Market-based organisation	Formal	Profit	Private	No
Community (collectivity)	Informal	Non-profit	Private	No
Residents (individuals)	Informal	Non-profit	Private	No

social housing providers; the market-based organisations (e.g. ESCos, banks), mainly driven by economic purpose; the community, characterised by a heterogeneous group of actors (e.g. organisations, foundations, associations, cooperatives), mainly operating to promote social and environmental sustainability; the residents, intended here as individuals representing personal interests. As identified by van Bortel (2011), these groups are delineated by three conceptual borderlines: the border between formal and informal organisations, the one between profit and non-profit actors, and the last distinction between the public sector and the private one. One conceptual borderline has been added to the framework (Table 4.1), namely the border between actors providing Services of General Interest (SGI) (European Commission 2011) and the ones providing services out from the SGI classification.

In the Italian framework, the regulation on the public housing stock is provided at regional level. Public housing management is up to the owner, either municipality or public housing associations (i.e., former IACP – *Istituti Case Autonome Popolari*), with the exception of the Emilia-Romagna and Tuscany Regions, which have separated the two roles and have transferred the ownership to the former, while the latter are in charge of the stock management.

The housing providers are therefore responsible for the municipalities' housing stock according to the rules defined by each Italian Region on housing allocation, rent calculation, mobility within the housing stock, and in some Regions also on households in arrears and property alienation. Roles and responsibilities are further specified in Table 4.2.

Energy Service Companies (ESCo) are for-profit or non-profit organisations specialised in providing a range of energy services to their clients. They promote energy efficiency and water consumption reduction on the premises of their customers. The building occupants then benefit from the energy savings and pay a fee to the ESCo (e.g. usually a higher energy bill than actual consumption, but still lower than the one prior renovation) for the whole payback period. Depending on their agreement with the client, ESCos take project performance

Table 4.2. Actors involved in regulation, provision and management of Italian public housing. Source: author's elaboration, adapted from Federcasa (2015).

	Central government	Regional authority	Municipality	Public housing provider (former IACP)
Housing allocation	Guarantees the coherence of criteria among Regions	Provides the regulation	Responsible of public procurement procedures and allocation list	Manages the allocation list and fixes the rent for each household
Rent calculation	n.a.	Provides the regulation	n.a.	Applies the rent levels
Regular management	n.a.	Provides the regulation	n.a.	Draws up the management regulation and the rental contract
Check of the allocation criteria	n.a.	Provides the regulation	Checks prior to the allocation	Checks the persistence once every two years
Check of the persistence of allocation criteria	n.a.	Fixes the criteria	Revokes the allocation	Takes care of the effective leave
Sell of dwellings	Defines prices and characteristics of beneficiaries	Gives approval to the sales plan	n.a.	Elaborates the sales plan

risks and the implementation risk. This is done through the Energy Performance Contract (EPC), which can either be in the form of a shared savings contract or a guaranteed savings contract.

In Italy in 2017, certified ESCos have increased by about 30% compared to 2016, with a consequent increase in employment. The growth in 2017 has been greater than the total recorded in the period 2012-2016, both for number of enterprises (75 more) and for the number of employees (2.476 more, about 34% of increase) (Info Build Energia 2018).

Communities and residents have been so far less involved in renovation of the housing stock and regeneration process than the other actors described above. Especially tenants living in social housing stock have been considered as a target group, rather than active stakeholders to be engaged for the success of the transformation process. Community is here intended as comprehensive of various forms of associations, formally or informally set-up. They exist over different levels (local, global), different spatial settings (urban and rural) and they are dynamic and constantly changing. In the broadest sense, sustainable communities actively and cooperatively work to reduce their environmental impacts both locally and globally, and to foster economic and social wellbeing. From a theoretical point of view, sustainable communities can be described either from the perspective of infrastructure and planning (e.g. neighbourhoods, land-use policy, housing) or from the social context by focusing on social relations, social practices, lifestyles and governance. From the citizen perspective, reflecting on complex issues as sustainability, climate change and regeneration from the communities' perspective can help to ground the actions and to make them more tangible. Regenerating existing communities through the increase of energy efficiency in buildings and actions to support a sustainable lifestyle requires the participation of individuals prepared to embrace change and to support the transformation process that can last several years.

Implementing an integrated approach is the overall aim of regeneration programmes. In the case of public housing, in addition to the physical renovation, these comprises a number of linked policy areas such as citizens' empowerment, employment creation, crime prevention, energy efficiency and environmental improvement. The principles of cooperation and coordination of different actors are seen as crucial to effectively implement these programmes (Czischke and Pittini 2007; Santangelo and Tondelli 2017b; Governa and Saccomani 2009): most of them include mechanisms of public participation, and social housing providers work in partnership with other public, private and social agencies involved in initiatives of urban regeneration.

The redevelopment of the public residential assets aimed at improving energy efficiency in Italy over the last decade have essentially been driven by two factors: reducing the costs associated with the ordinary maintenance of the stock and contributing to the energy reduction goals set at European and national level, to avoid penalties. The implementation of the interventions has seen in many cases the involvement of the ESCos, which operate by setting a payback time during which the tenants benefit from a limited energy and economic savings, reduced by the amount allocated to the ESCo for the recovery of the investment. In this scenario, there is an overcoming of public-private dualism, in which the public administration provides the funds assuming all the risks, while the private actors just perform their work as contractors. However, transformations and co-benefits which are not easily quantifiable in economic terms are difficult to be implemented, as for the regeneration of the public space and the initiatives to raise awareness among occupants on energy efficiency and energy behaviour (Santangelo and Tondelli 2017a).

4.3. Occupant behaviour, public housing and energy poverty

Historically, an EU-wide definition of energy poverty or vulnerable consumers has been deliberately avoided by the institutions because of the difficulties in designing a concept which fits with all existing national contexts (Bouzarovski 2018). Different Countries require different policy mixes and measures to address energy poverty. However, the lack of a common definition has also been identified in literature as the fundamental cause of the insufficient measures taken to date and the primary barrier to more coherent EU actions (Thomson et al. 2016).

The driving actor in pushing an EU energy poverty policy forward has been the European Commission. Indeed, following numerous failed attempts to create a common energy policy framework prior to 2007, the Commission has ensured that energy poverty forms an important strand of the now wide-ranging EU action in energy (Bouzarovski 2018).

The energy poverty, also known as fuel poverty, can be understood as a phenomenon encompassing the various sorts of affordability-related challenges of the provision of adequate energy services to the domestic space (Thomson et al. 2017). These typically represent situations in which households with access to modern energy infrastructures cannot comfortably satisfy their energy service needs, due to their inability to afford sufficient energy services and/or due to the costs they have to bear for those energy services (Ürge-Vorsatz and Tirado Herrero 2012).

According to Housing Europe (Pittini et al. 2017), almost 1 out of 10 (9.4%) households in the European Union are unable to keep their homes adequately warm. While the proportion of households in energy poverty across Europe has remained relatively stable at around 10%, there are significant variations both across Countries and in terms of the changes over time. For instance, in the UK the average social rented home is of significantly higher energy efficiency than any other tenure. Despite this, with 22% of social rented households saying that they are unable to keep their home adequately warm the proportion is higher than among home-owners or private renters reflecting the concentration of low incomes in social housing.

Somehow surprisingly, the highest levels energy poverty can actually be found in Countries of South and South East Europe. In Bulgaria, Greece, Cyprus and Portugal more than 20% of all households declare that they are unable to keep their home adequately warm (Pittini et al. 2017). While some of these high rates are certainly the outcome of the low quality and low energy efficiency of residential buildings, the recent growth in energy poor households in Countries such as Greece, Italy and Spain can at least partially be explained with the worsening social and economic conditions in the aftermath of the financial crisis and austerity measures. Lower levels of energy poverty are observed in Scandinavian and other Northern and Central European Countries, including Germany, the Netherlands or Austria. In these Countries, less than 5% of all households report that they are unable to keep their home adequately warm m (Pittini et al. 2017). In many Eastern Europe Countries, inadequate housing quality is still a big issue, with potentially a huge negative impact on health. The phenomenon does not only concern social housing sector, but also home-owners living in dwellings badly in need of renovation, as in Bulgaria, Estonia, Romania, where, however, residents cannot afford it without public support.

Therefore, it is evident that energy performance of the housing stock can have a significant impact on the cost of utilities and contribute to energy poverty. Nevertheless, building characteristics alone do not explain the energy consumption, and energy behaviour and practices should be taken into account too. Energy efficient technologies, together with awareness on energy behaviour and information on how to reduce the energy consumption have the potential to alleviate energy poverty. However, as noted by Ürge-Vorsatz and Tirado Herrero (2012), due to a number of barriers (i.e., relatively long payback times, restricted access to credit, lack of appropriate financing schemes, low awareness of decision-makers about the alternatives, split incentives between tenants and owners), deep efficiency is often not applied on a private investor or market basis in spite of its larger societal benefits. However, in line with evidence from DellaValle (2019), this work is aimed at showing the positive role behaviour can have on reducing energy consumption and alleviating energy poverty, even in the case of non-physical intervention on the building.

To summarise, technology and climate change are two strategic directions likely to affect the direction of the EU energy poverty policy in the coming years. Smart metering, a growing priority of EU energy policy, holds the potential to combat energy poverty to some extent, although it also requires careful considerations on the role of user behaviour (Darby 2012). Low-carbon urban and regional development policies also hold significant energy poverty reduction opportunities, especially if justice contingencies are taken into account (Bouzarovski 2018). There are also important intersections between climate change policy and energy poverty policy (Ürge-Vorsatz and Tirado Herrero 2012), not only in terms of mitigation efforts but also in relation to the impacts of global warming on the need for additional energy appliances at home, such as space cooling systems.

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››› 5.
No “one-size-fits-all” solution: proposals for addressing consumer behaviour through different policy instruments by different actors

As result of the previous chapters, measures tackling user behaviour to reduce energy consumption in buildings have been identified as the most urgent and convenient for all the scenarios analysed, especially when it comes to the renovation of the existing building stock.
However, no “one-size-fits-all” solution is possible due to particularities across household and building characteristics (Barbu et al. 2013; Karvonen 2013; Tweed 2013; Economidou 2014; Bedir 2017).
The next step foresees the analysis of the Italian public housing sector in terms of actors involved, barriers to the implementation of renovation and the identification of drivers to overcome the barriers. Several measures are suggested to demonstrate to what extent household behaviour can be embedded in the policy instruments and tools currently in place through the description of practical solutions. Benefits of accommodating consumer behaviour into policy instruments are also highlighted, and a decalogue made by ten proposed solutions tailored to the public housing sector is framed.

5.1. Analysis of actors, barriers and drivers

The Italian public housing sector has some specific characteristics which make possible to identify the actors involved when it comes to the energy management and renovation of public housing stock. The extreme fragmentation of housing demand, the increasing energy poverty of tenants living in public buildings, the overall decline of public spending on the housing sector, and the ongoing redefinition of the role of public authorities are only some of the elements describing the Italian housing issue. New conceptual and methodological advancements are needed in order to properly address housing needs, both from the point of view of scholars and of decision-makers (Governa and Saccomani 2009), where the provision of information, awareness raising and new skills can be the driver not only for the renovation of the public housing stock, but also for a new housing policy based on providing housing as a service, rather than just an asset.

Actors

Public rental housing stock in Italy can either be owned by municipalities or public housing providers, depending on the regional laws. In both cases, the latter are responsible for the management, allocation process and maintenance, while

the former, whenever owner, is responsible to transfer to the latter the necessary resources to deliver a proper service. The book takes as a reference the roles and responsibilities that apply in the Emilia-Romagna Region.
Beside what happens in the public housing sector, it must be acknowledge that cooperation between public and private sector in Italy has achieved a remarkable widespread over the last two decades (Copiello 2015). Energy Service Companies (ESCos), and more generally private-market-parties and investors have been increasingly involved in the renovation of the public housing stock. However, when it comes to the reduction of energy consumption, the tenants cannot be left apart since household behaviour has been found to significantly contribute to the energy usage in dwellings (Janda 2009; Guerra-Santin and Itard 2010; Gupta and Chandiwala 2010; Ben and Steemers 2014; Santangelo et al. 2018).
Despite the clarity of the actors involved, the relationship among them is rather than simple and does not follow a straight path, and a number of barriers have been identified to the energy renovation of the building stock (BPIE 2011; Achtnicht and Madlener 2014; Economidou 2014; Pasetti 2016; Caputo and *Pasetti* 2017; MISE 2017). Starting from the ones analysed and categorised by the Building Performance Institute Europe in 2011 and updated in 2013 (BPIE 2011, 2013), this work describes to what extent those barriers apply to the renovation of the Italian public housing sector, and how the consumer behaviour can be turned as a driver to effectively deliver energy savings.

Barriers
Improving the energy performance of buildings is a consequence of a multi-stakeholder decision process (BPIE 2011). This is also true for the public housing sector, although the limited number of stakeholders and the large building stock make it a particular favourable case study to understand the barriers and challenges that policy-makers have to face to improve the public housing stock. Evidence from research and practical experiences have highlighted that consumers and investors, either private or public actors, are not keen on investing in energy saving (BPIE 2011). A study performed by the International Energy Agency (OECD/IEA 2014) highlighted that, under existing policies to all sectors, two-thirds of the economically viable energy efficiency potential through 2035 will remain unrealised, due to information failures, split incentives, subsidised pricing of energy, inadequate pricing of externalities and a shortage of financing. But mainly, due to the fact that energy efficiency represents a negative quantity (i.e. energy not expended), it is often perceived as an intangible concept. Its societal value is not clearly apparent to investors, consumers and policy-makers. However, people's decisions are affected by a number of factors, and the human dimension has started to be further investigated not only in the design sector, but also in the policy field (Santangelo and Tondelli 2017a; D'Oca et al. 2018) as a turning point to deliver energy efficiency.
When it comes to the renovation of the Italian public housing sector, the barriers that emerge can be classified as in Figure 5.1.

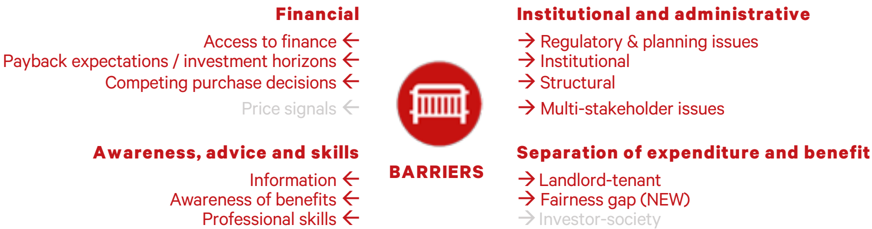


Figure 5.1. Classification of barriers to the renovation of the Italian public housing stock. Source: author's elaboration, adapted from BPIE 2011, 2013.

Financial barriers are probably the ones which firstly come up, since the implementation of renovation programmes requires considerable resources, particularly limited for public administrations, always seeking to do not exceed the annual disposable budget. Financial barriers can be classified as: lack of funds or access to finance, particularly prevalent for public authorities but also private bodies, looking for securing finance on acceptable term in order to be more competitive on the market. However, in many cases the barrier is more linked to lack of awareness or lack of interest, rather than lack of funds (BPIE 2011). For example the implementation of soft measures as information programmes and behaviour change campaigns has been demonstrated to be cost-effective over the long-term, to have low initial costs and to produce a positive Net Present Value (Santangelo and Tondelli 2017a). Nevertheless, they have been seldomly applied.

The payback expectation / investment horizon is a major concern of ESCos, which base their business on their capability to recover their initial investment through the energy saving, and for public authorities too, struggling to make the renovation of their public stock appealing and profitable. However, the longer the payback time is, the less is the interest of private organisations to invest. In this scenario, the household behaviour takes also an important part, since the payback period is also linked to the change of consumption patterns from tenants, who need first of all to be informed and secondly to be motivated, in order to deliver energy savings (Santangelo and Tondelli 2017a).

Competing purchase decision is also an issue that public administrations usually have to face, since investments on energy efficiency are not visible and, therefore, less attractive (BPIE 2011). This is particularly relevant for soft measures addressing consumer behaviour, and it also applies to public housing low-income tenants who struggle to afford the energy costs, and find easier to pay a recurring cost than to make an investment (e.g. buy more efficient lights and other appliances) that is perceived as high (Pasetti 2016).

The price signal, the last one among financial barriers included in BPIE (2011), has not found to be relevant for the Italian public housing sector, since it regards the lack of motivation for the majority of consumers to take actions due to the small share of the housing energy costs. On the one hand, in Italy this issue is not a barrier since the energy prices for domestic consumers are among the highest in Europe, far above the average price for EU Member States (European Union 2017). On the other hand, tenants in public housing are not supposed to implement renovation measures, which are responsibility of the public authorities owning the housing stock.

There is a wide range of *institutional and administrative barriers* that applies to the renovation of the public housing stock, affecting both the implementation rate and the ambition of the renovation process. According to the Building Performance Institute Europe (BPIE 2011, p.57), *"evidence from Italy indicates that fragmentation, delay and gaps in the regulatory action of public planning have not allowed the public sector to be the driver for improved energy efficiency in buildings that it should be"*. Indeed, results from Chapter 1 highlighted the inability of public authorities in recognising urban planning as the discipline able to deliver significant changes in the adoption of energy efficiency measures. Institutional barriers apply both to the public sector and to the private one. In case of public sector, there might be institutional barriers in using new services (i.e. as renovating by involving ESCos in the process) or building new partnership (e.g. with the tenants, by involving them to agree on certain energy saving targets). In case of private sector, there is a bias among institutional investors more familiar with large-scale financing, rather than generally smaller projects perceived as more risky (BPIE 2011), as the renovation of the public housing stock might look like, also due to the general lack of trust on public housing providers from tenants and private stakeholders.

Structural barriers are the ones faced by public housing providers, due to the age and poor energy efficiency of the building stock. In Italy demolition is considered to be the last option, also due to the difficulties related to the reallocation of households, therefore, the quality improvement of the buildings is subjected to the relative lower energy efficiency, which is inversely proportional to the age of the building stock.

Multi-stakeholder issues are a significant barrier for the renovation of the public housing stock, due to the mix of tenures of the multi-dwelling buildings. In fact, from the 1990s, several dwelling sales campaigns have been promoted by public authorities, resulting in a mix of multiple family-owners and public owners, making even more difficult to take decision on maintenance and renovation works than in case of multi-private ownership.

Awareness, advice and skills barriers are the ones more cross-sectoral to all the actors involved. Ambitious renovation requires all the stakeholders to get involved to take their part, and particularly tenants who have a key but underestimated and unexplored role, unless right advices and proper information are available. The human factor and the provision of new skills and knowledge are also relevant for ESCos, usually discouraged from taking deep renovations of the buildings, and for public authorities and housing providers, to overcome the inertia of the status quo and the difficulties in assessing the impact of measures and managing the complexity related to multi-stakeholder involvement. The awareness of cost-effective energy saving opportunities has been increased but remains still low, while the focus is on individual solutions and the holistic approach – at the basis of the urban planning approach – still remains unexplored.

Separation of expenditure and benefit is the last barrier to be presented. It is related to the fact that the owner and the user of the dwelling are two different entities. For the owner, any investment has to bring a benefit which is not necessarily linked with energy savings, unless it is a situation where the landlord pays the energy bills and the energy consumption is included in the rent as a lump sum. Since the tenant does not own the dwelling, any investment in lowering energy bills has to be seen as financially advantageous for both actors, often resulting in no action taken (BPIE 2011). In case of renovation of the Italian public housing stock, the landlord-tenant barrier may apply caused by the impossibility of providers to raise the rent after the renovation, due to both legislative restrictions and low-income situation of tenants. However, due to the housing allocation system characteristics, an additional barrier should be added to this category, namely the *fairness gap barrier*. The allocation of dwellings is based on a waiting-list system: low-income households who meet specific criteria (i.e. a minimum period of residency in the city or region and income not exceeding a certain level) can apply for a rented public dwelling. The rent is calculated according to the income level and does not take into account the dwelling characteristics, despite some Italian regions recently revised the regional legislation to accommodate the possibility – rather than the duty – to do so (Santangelo and Tondelli 2017b). The vacant housing units are then allocated according to the family size. Each family, once gets on the top of the waiting-list, can normally choose among two or more options. However, the energy efficiency of the dwelling is not taken into account neither as an allocation priority, nor in the calculation of the rent. Therefore, unfair situations arise among low-income tenants with the same difficulties in meeting housing and energy costs, whit tenants paying the same rent but having different expenditures for energy services and experiencing different comfort and healthy housing conditions. Once the housing stock is renovated, especially when ESCos are involved and an Energy Performance Contact (EPC) is signed among housing providers, ESCos and tenants, the fairness among households is again compromised due to the higher energy costs than the real consumption that tenants of renovated buildings have to pay, to allow the ESCos to recover the initial investment. While homeowners in the private housing market may decide to renovate their houses and to sign an EPC, to then benefit of energy and money saving after the payback period, public housing tenants are required to pay the renovation costs without having the housing right to live in the same dwelling after the EPC ends (Proli et al. 2016). The fairness gap is, therefore, an additional barrier that needs to be overcome to avoid exacerbating the relationship between housing providers and tenants, and to facilitate an increasing public housing renovation rate.

Drivers

While there are several studies available describing and categorising the barriers to the renovation of the building stock for improving the energy performance (BPIE 2011; Achtnicht and Madlener 2014; Economidou 2014; Pasetti 2016; Caputo and Pasetti 2017; MISE 2017), the drivers to overcome those barriers have been less investigated (Pasetti 2016), and the gap can be explained by the high dependency of drivers to the specificity of different contexts in different countries. The aim of this work is to provide an insight on the role of the human factor to boost the renovation of the Italian public housing stock from a planning perspective, by suggesting improvement of policy instruments and planning tools. Therefore, since barriers can also be reversed and seen as drivers, the awareness, advice and skills element presented above is now taken as the main driver to the implementation of effective building renovation strategies and plans (Figure 5.2). Individuals need correct information for a sustainable choice. Without an appropriate frame of reference, users cannot determine whether their energy consumption can be reduced or not (Gyberg and Palm 2009; Janda 2009; Jain et al. 2012, 2013; Barbu et al. 2013; Frederiks et al. 2015), and whether their behaviour can be improved to reduce consumption and increase sustainability. Therefore, information and feedback play a significant role in raising energy awareness and changing consumer attitudes towards energy consumption. Understanding the benefits is not only useful for the households, but also for the public housing providers, who often lack of competences to address consumer behaviour both within the daily management operations and when it comes to the building

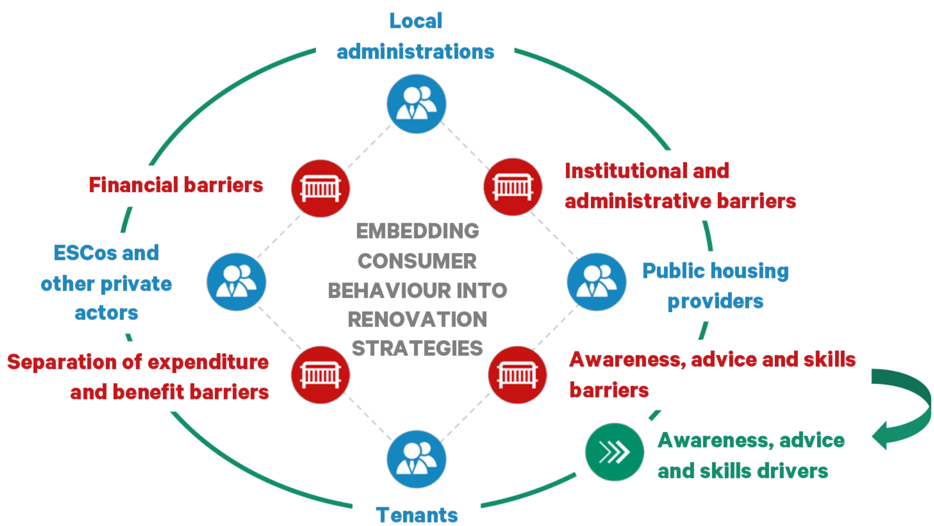


Figure 5.2. Interplay between actors, barriers and drivers. Source: author's elaboration.

renovation. The improvement of professional skills is also beneficial for private actors as ESCos and construction companies, more oriented to technological measures, rather than holistic renovation approaches including information and awareness measures. The role of occupants in delivering effective energy saving is also neglected from the local authorities, that need to increase their understanding of the consumer behaviour impact and the possibilities to address it by including appropriate measures in their policy instruments.
Actions to address the barriers described above should be taken to unlock the energy saving potential of the Italian public housing stock. These measures include, but are not limited to, new policies and regulatory initiatives from a planning perspective, and new measured tailored to specific needs. Hence, they are further discussed in section 4.4.2.

5.2. Description of proposed solutions

To effectively enforce energy issue within the public housing stock, the description of the interplay between actors, barriers and drivers should be completed by adding information, on the one hand, on how to deliver behaviour awareness campaigns, tailored feedback and information to households; on the other hand, on how to enable local authorities, public housing providers and private actors to take actions to trigger such behaviour change. Thus, ten Proposed Solutions (PS01-10) have been identified and grouped in two main categories (Figure 5.3).

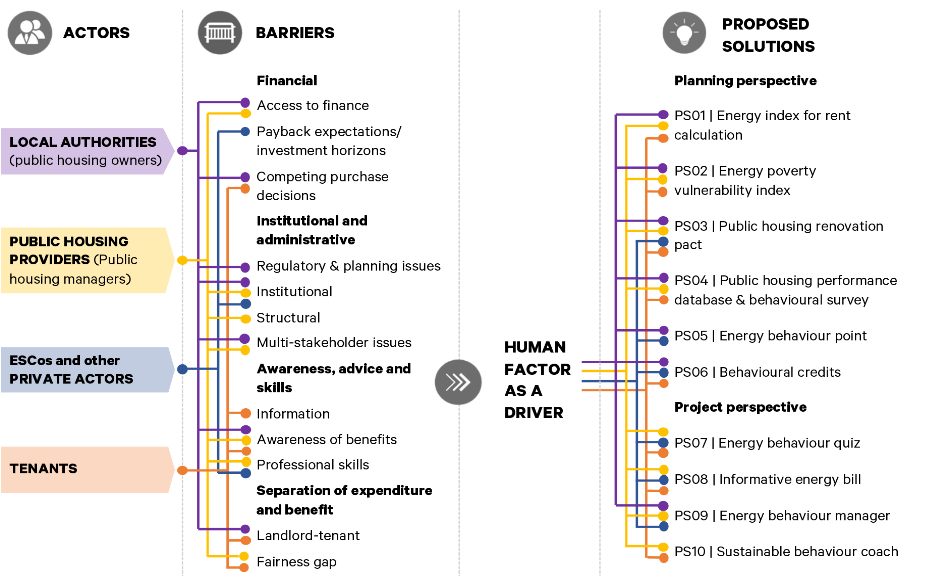


Figure 5.3. Overview of actors, barriers, drivers and proposed solutions. Source: author's elaboration.

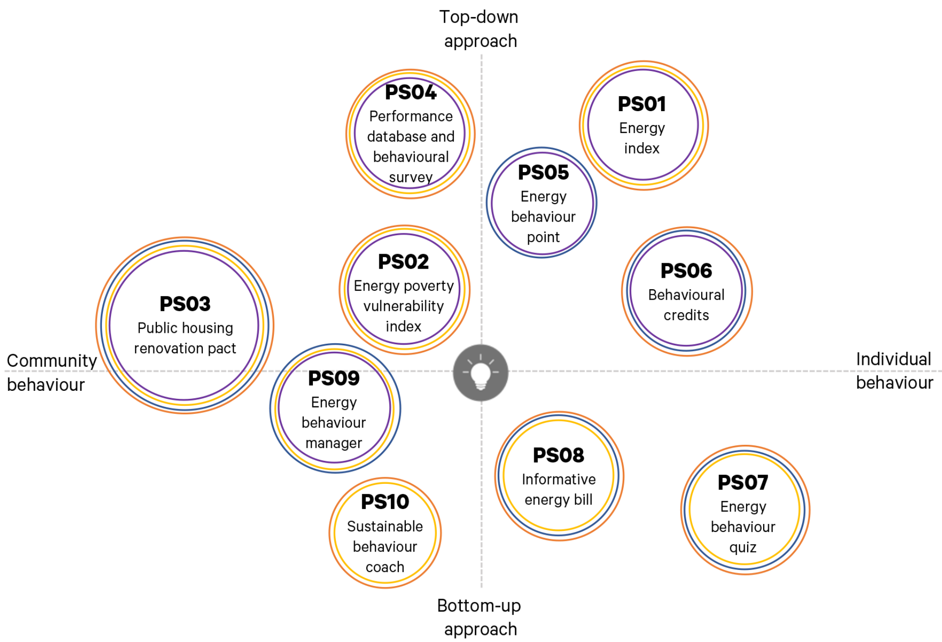


Figure 5.4. Positioning of proposed solutions in relation to type of approach and behaviour. Source: author's elaboration.

The first group of proposed solutions (PS01-06) includes proposals which are aimed at improving the planning process. They are mostly top-down proposals suggesting a process change to deliver a long-term impact on public housing management and renovation, rather than the implementation of a single project-tailored measure.

PS01, PS02 and PS06 are designed to embed user behaviour into economic and welfare instruments. PS03 is aimed at improving the policy level of building renovation through the proposal of a new policy instrument, while PS04 and PS05 are tailored respectively to increase knowledge among stakeholders and to raise awareness among households.

The project perspective is then included in the actions described afterwards (PS07-PS10), tailored to demonstrate the short-term impact of specific tools. PS07 is designed to get information from occupants, while PS08 and PS10 are aimed at providing information and feedback to the occupants. Finally, PS09 is suggested to increase knowledge and skills at organisation level. Figure 5.4 shows the positioning of the proposed solutions in relation to the type of approach (i.e. top-down or bottom-up) and the behaviour addressed (i.e. community or individual). The coloured circles give indications about the type of actors involved, while their sizes inform on the number of actors involved.

The ten factsheets that follow further describe the proposed solutions.

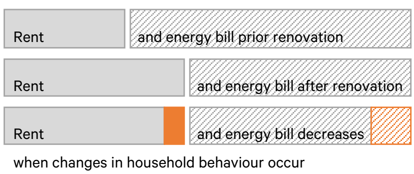
PS01 | Energy index for rent calculation

Actors to be involved

- Local authorities
- Public housing providers
- Tenants

Main features

The energy index is aimed at embedding energy issue into social rent calculation for public housing stock. Currently, the rent calculation is based on income categories, rather than dwelling characteristics, and the housing renovation does not lead to a rent increase.
On the one hand, the existing system does not motivate households to adopt energy-saving behaviour, since they are neither aware of the energy performance of their accommodation, nor required to pay attention to energy consumption after retrofit interventions. On the other hand, it leads to inequalities among tenants, since households within the same low-income category might be allocated to dwellings with totally different building characteristics, resulting in different energy costs.
The proposed energy index is based on a score system. Different energy-related building characteristics lead to different scores. Public housing providers may fix certain prices per point, tailored to the income categories. As the energy index increases, the rent increases according to the price per point of each income category. Afterwards, some reductions both for the rent and for the energy bill are foreseen if users adopt sustainable behaviour. There is no standard behaviour, therefore, households should agree their sustainable behaviour targets in cooperation with the sustainable behaviour coach (PS10).
Rent decrease is an economic incentive that could be quantified as a percentage of the energy-savings.



Pros

It contributes to ensure energy justice (Jenkins et al. 2016) for low-income households in energy poverty conditions living in dwellings with higher energy expenditures than those renovated.
Rent increase after renovation helps housing providers to properly manage the housing stock.
It contributes to reduce housing allocation inequalities among tenants.
It is an energy behaviour awareness tool, since it is expected to stimulate and motivate behaviour changes in order to save money.

Cons

There are legislative barriers, since in Italy only few regional legislations (Santangelo and Tondelli 2017b) and public housing regulations foresee the possibility either to increase rent after renovation, or to calculate the rent according to energy performance.
It only works if the benefits (e.g. increased earnings for housing providers; lower expenditures for households) are split among the two actors. However, the incentives both for housing providers and for tenants are difficult to realise if the renovation is carried out by an ESCo due to energy costs saving for investment repayment.
It could lead to stigmatisation and social exclusion, with the poorest unable to afford the rent increase.
The calculation of the rent increase should be based on real consumption data, rather than energy simulation performance, to avoid overestimation in energy savings.

PS02 | Energy poverty vulnerability index

Actors to be involved

- Local authorities
- Housing providers
- Tenants

Main features

The energy poverty vulnerability index is aimed at increasing knowledge among local authorities and housing providers on the vulnerability level of households to energy poverty. Energy poverty, also known as fuel poverty, is defined as a situation where households cannot access to and afford adequate level of heating or other required energy services to meet their basic needs, or they cannot afford other necessary goods due to the high utility costs (see Glossary section).
The energy poverty vulnerability index is a composite index based on:
i) dwelling characteristics and energy index (PS01);
ii) household characteristics (e.g. family size, composition, age);
iii) household behaviour assessed through questionnaires and (smart) meter readings of the actual energy consumption.
The index can be reduced both by moving to another dwelling with higher energy performance, and by optimizing behaviour. Since the former is seldomly an option, due to the scarce rotation rate of public housing stock, and the social instability that such change may cause, raising awareness on behaviour represents the best option for the short-medium term. Behaviour changes should be supported at community level through a set of measures and behaviour awareness campaign, avoiding to blame the victim, but providing a knowledge framework for a pro-environmental choice.
As the index increases, additional welfare measures should be put in place by the local administration to mitigate the energy poverty condition.

Pros	Cons
Knowledge increased among local authorities, responsible to address energy poverty issue. Improvement in the definition and measurement of energy poverty phenomenon, by including the household behaviour as one of the possible drivers to decrease energy poverty vulnerability.	Mapping households living in public housing stock is a time-consuming activity which requires the collaboration between local authorities and public housing providers, to combine different data sources. New skills should be developed among public authorities to tackle the energy poverty phenomenon and to design welfare measures to address it. There is the risk to blame the victim and to put on vulnerable tenants the responsibility of wasting energy, while high energy consumption is always due to a combination of building characteristics and behaviour, not behaviour alone.

PS03 | Public housing renovation pact

Actors to be involved

- Local authorities
- Housing providers
- ESCos and other private actors
- Tenants and tenant’s union

Main features

The public housing renovation pact is an agreement jointly signed by the municipality, the housing provider, the tenants and the private entity managing the renovation phase, if the participation of an ESCo applies.

This solution is aimed at building trust among the stakeholders involved and at defining common goals and actions to deliver improvements in building energy performance and energy savings. Interventions should be based on a combination of practices, from micro-urban regeneration actions involving the tenants with a bottom-up approach, to top-down and physical interventions on the built environment. The definition of quantities (i.e. intervention areas, expected energy savings), responsibilities and expected benefits should be also included.

The pact should be the opportunity to establish long-term engagement with tenants and to raise awareness among households on the impact of their behaviour on energy consumption. The signature of the pact could be celebrated to also launch the behaviour change campaign as an opportunity to adopt pro-environmental behaviour and to reduce energy costs.

Another opportunity to do not miss should be the regeneration of the public indoor and outdoor spaces. Although asking to the market to incorporate the urban regeneration benefits is still a challenge, the interventions to improve the outdoor space (i.e. to recover rainwater, to increase soil permeability, to recover abandoned spaces for vegetable gardens, coworking spaces and other community activities) may contribute to give visibility to the renovation process inside the buildings to citizens living outside.

Pros	Cons
Increased social sustainability through the involvement of the target group in the intervention strategy definition. Co-ownership of targets and results.	Difficulties in reaching consensus among all the actors, due to the different personal motivations and interests, but also due to the lack of trust between housing providers and tenants.

PS04 | Public housing performance database and behavioural survey

Actors to be involved

- Local and regional authorities
- Federcasa (umbrella organisation of Italian public housing providers)
- ENEA (Italian National Agency for New Technologies, Energy & Sustainable Economic Development)
- ISTAT (Italian Statistic Bureau)
- Energy utilities

Main features

The monitoring database is aimed at investigating the state of the art of rental public housing stock at national level, and at building a knowledge baseline for the development of strategies and tools to renovate the housing stock and addressing the impact of behaviour on energy savings.
On the one hand, it should collect data updated on yearly bases on building characteristics (e.g. insulation, type of glazing, ventilation, heating and domestic hot water systems) and energy-related information such as the estimated energy performance based on energy labels, the actual energy consumption (i.e. per housing unit), the energy consumption breakdown for consumption end-use categories (e.g. heating, electricity, water), the energy poverty vulnerability index (see PS02).
On the other hand, technical and energy data should be coupled with data on household characteristics, behaviour and energy awareness. Data on occupant characteristics include income level and type, household composition, number of occupants, occupants above and below 65 years old, number of children and age of children. Information should be collected by housing providers, since they are responsible of the allocation procedure.
An ambitious survey should be promoted to investigate behaviour in the pre-renovation phase (Gupta and Chandiwala 2010), while a follow-up survey should follow the first one once the behaviour awareness campaign has been implemented and renovation measures introduced, to monitor the behaviour changes (i.e. post occupancy renovation survey).

Pros	Cons
Knowledge baseline for the development of strategies and tools to renovate the housing stock and addressing the consumption behaviour impact on energy savings. The availability of building assets and energy-related information shows to private investors (e.g. ESCos) the high replication potential of interventions on the public housing stock. Joint efforts required from public and private bodies to build the database is a valuable interdisciplinary experimentation. The survey on behaviour makes possible to explain and to limit the likely gap between expected and actual energy performance.	High resolution data are not always available. Despite the Italian national legislative decree D.Lgs. 102/2014, implementing the Directive 2012/27/EU on energy efficiency requires the installation of meters to account energy at household level in existing buildings with central heating system, it has been seldomly implemented by public housing providers, due to lack of funds and separation of expenditures and benefits barrier.

PS05 | Energy behaviour point

Actors to be involved

- Local authorities
- Urban centres, public libraries and other public offices/facilities
- Private organisations as energy utilities, multi-utilities and ESCos interested in investments with a social revenue

Main features

The energy behaviour point is a permanent info point aimed to give information and to raise awareness not only among the public housing tenants, but also to the whole citizens, on the impact of household behaviour on energy consumption.
It should be located in a public place with high visibility and people flow (e.g. urban centres, public libraries), to turn the spotlight to the public housing stock as a public service, able to undertake innovations that can be beneficial for all the citizens.
Household recruitment to behaviour change projects largely relies upon communications materials. Studies have noted that engagement is constrained since energy consumption feedback often lacks salience for many householders. This is partly because energy is invisible and is consumed only indirectly, but also because the units of measurement of energy are confusing to many householders. Therefore, the energy behaviour point should provide evidence of the impact of household behaviour on energy consumption through interactive activities, games and quantitative results (i.e. not only in terms of direct energy units but also money saving and environmental externality units, as tree needed to offset emissions (Jain et al. 2013)).
Activities of the energy behaviour point should be coupled with the ones already in place. For example, Bologna SEAP foresees the energy point (i.e. “il punto energia”), an information desk for citizens who would like to get information on building renovation measures and enterprises on white certificate schemes. The energy behaviour point could, therefore, be extended to all citizens.

Pros	Cons
High visibility of the energy user behaviour topic, reducing lack of salience of energy feedback and energy invisibility. Twofold aim: tailored info to engage public housing tenants; general information to raise awareness among the rest of citizens.	Strong political commitment needed to make the proposal sustainable and effective

PS06 | Behavioural credits

Actors to be involved

- Local authorities
- Public/private companies
- Tenants

Main features

The aim of the behavioural credits campaign is twofold: on the one hand, to provide users with rewards to support their behaviour changes, as credits to be spent for certain services, according to the agreements with partner institutions; on the other hand, to build-up a complementary welfare system that provides direct benefits to those households committed to reduce energy consumption at home. In addition, this solution could also be beneficial for raising awareness among other tenants not part of the programme, to claim the same possibility, activating further bottom-up activities.
Behavioural credits can be gained through changes in energy-related behaviour. Direct or indirect feedback would provide the framework for making such change, informing the occupants on the impact of their current behaviour and the benefits of optimising it. For instance, the preferred set-point temperature can be reduced from 21°C to 22°, or the heating system can be turned off by reducing the thermostat when a room or the whole housing unit is empty. The behaviour changes can be reported through surveys and the answers can be matched with the data from smart meters, to provide then feedback to the occupants and to update the credit scheme.
A behavioural credit scheme should be built, either according to the amount of energy saved, or by assigning a weight to different behaviour changes according to the easiness to implement them.
Agreements should be signed between the local authorities and the public/private companies, to select the benefits and to fix the purchasing ability of the credits.
Successful similar experiences have been implemented in the field of sustainable mobility (e.g. "Bella Mossa", "WeCity", "Bike Challenge"). Examples of services are: selected food products, vouchers for the grocery store, public transport tickets, tickets for sport events, cinema or theatre.

Pros	Cons
The access to services at reduced price makes behavioural change desirable and its effect more tangible. Credit accumulation may allow to build gamification projects where different communities living in different districts might play with each other to gain more benefits to share with the community than the one that is possible to reach as individuals. It is a measure having a positive impact on the welfare system, since the credits can be spent to acquire other basic services at discounted fares (e.g. bus monthly/yearly ticket).	Investments for In Home Displays (IHDs) or other monitoring system should be foreseen in order to be able to quantify behaviour change effects on energy savings. IHDs can provide frequent and direct feedback which can foster the commitment to the initiative.

PS07 | Energy behaviour quiz

Actors to be involved

- Housing providers
- ESCos and other private actors
- Tenants

Main features

The main purpose of the energy behaviour quiz is learning-by-doing. Differently from energy questionnaires that are mainly aimed to gather information to be then processed for providing feedback to the occupants, the energy behaviour quiz is intended as a tool to raise awareness while, at the same time, providing knowledge on the current situation. In addition, another issue which makes the energy behaviour quiz different from a traditional survey, is the fact that the quiz can be performed by each occupant of the housing unit, while answers to surveys are usually done only once per household. Inviting each occupant to take time for the quiz will raise awareness of all the household members taking part to it, not only the household representative as the case of the survey. The multiple replies can also activate gamification process among the family members, to make each other aware that each person has a role in optimising energy consumption.

The energy behaviour quiz should be organised to associate a score to the multiple answers, so to provide to the users the results in real time in terms of consumer profiles. Some examples are provided below:

- energy saving super star › “Perfect score! When it comes to put energy efficiency into practice, you know your stuff”
- energy saving trainee › “You are on the road to understand how energy affects our everyday lives”
- energy saving rookie › “There is so much more to learn, but taking this test is a good start”

Examples of questions can include:

“Which uses less energy – taking a hot bath or a hot shower?”

“Each degree higher on the thermostat can save how much on your heating costs?”

Pros	Cons
Learning-by-doing process. The quiz does not require so much time. It can be performed as a game to understand who is more aware on energy consumption within the family. It can provide some baseline information useful, on the one hand, to the housing providers to then build an informative campaign on the current knowledge and awareness; on the other hand, to the ESCos and other private actors involved to understand actual knowledge of users about the technology installed in case building renovation occurs.	It could not be taken seriously if not adequately promoted and supported by housing associations, leading to misleading knowledge. It can create expectations among households. Therefore, housing providers should plan the energy behaviour quiz as a first step of an energy informative campaign, not as a one-time initiative.

PS08 | Informative energy bill

Actors to be involved

- Housing providers
- ESCos, energy utilities, accounting companies, other private actors
- Tenants

Main features

Provision of a more frequent and informative energy bill has proven to lead to energy conservation (Wilhite and Ling 1995; Barbu et al. 2013; Jain et al. 2013). Households can see a reduction in their energy bills by changing their energy behaviour and reducing consumption.

To make energy bills more informative, can include:

- charts which visualise trends on household energy use;
- comparisons of energy use (e.g. to the previous month or the same month in the previous year);
- comparisons to selected user groups (e.g. households in the same building/street). The comparisons with similar households enable customers to easily understand whether their consumption is low or high. Benchmarking makes possible to rank energy performance in a way similar to that of the efficiency of home appliances.

With billing information sometimes “more” is “less”. Occupants need advice easy to understand and feasible to put in practice. Consumers are not always motivated only by saving money, ecological reasons and social norms can be sometimes more important.

The well-being aspect of informative energy bill includes the sense of satisfaction from personal improvement, and improvement against other people behaviour, individually or as a group, depending on the benchmark provided. Tips would provide respondents with ideas about how they could conserve both energy and money. Smart meters alone would not deliver significant changes in consumer behaviour on their own, but they do constitute an essential part of wider behaviour change programmes, as they provide information necessary for more informed decision-making on energy use.

The key is to provide householders with more informative bills on how much energy they use and how much it is costing them, either in monetary or environmental terms. Indirect feedback like this could reduce energy consumption by 5-10% (Barbu et al. 2013).

Pros	Cons
It enables tenants to receive indirect feedback on their energy consumption, tips to save energy, advices on behaviour change and the impact of such changes on the energy consumption. It is a key measure in case smart meters are not installed. However, if they are operating, informative energy bill can represent a complementary feedback to the direct one resulting from the smart meter readings done by the occupants.	Making the energy bill more informative requires an initial effort to change the current bill layout, to make new calculations starting from the data available. Personalised tips to occupants require skills in the energy field that housing providers not always have. Therefore, cooperation with other public or private actors is necessary, as well as the appointment of an energy behaviour manager. High resolution data are not always available.

PS09 | Energy behaviour manager

Actors to be involved

- Local authorities
- Housing providers
- ESCos and other private actors

Main features

The energy behaviour manager is a new professional figure that public and private organisations could engage and add to their staff in order to be able to deal with the impact on energy consumption caused by household behaviour.
The expert is expected to provide innovative ways to include considerations on behaviour into the strategies and measures to be implemented, and to provide an expertise currently missing. In fact, energy managers, mandatory by law for local public administrations with more than 10,000 inhabitants, do not necessarily have expertise on occupant behaviour and tools to assess it. However, this compulsory activity is scarcely implemented (Caputo and Pasetti 2015).
In the municipality context, the energy behaviour manager can ensure that both the energy and planning tools are designed to take into consideration the impact of user behaviour. For instance, he/she should be responsible to design behaviour awareness campaigns, to set-up the behavioural credits scheme (PS06), to coordinate the activities of the energy behaviour point (PS05) and to design the policy instruments to tackle energy poverty through behaviour change initiatives.
Housing providers can also benefit from the integration of the energy behaviour manager expertise into their staff, since he/she will be fundamental to coordinate data collection (PS04), to coordinate the sustainable behaviour coach (PS10) in designing, delivering and analysing survey results on energy behaviour, to design the informative energy bill (PS08), and to provide support into the daily operations involving the tenants.
When it comes to private actors, it would be more than beneficial to add the energy behaviour manager to the staff of an ESCo, for example, since behaviour has been demonstrated to be a key component of the energy consumption, and to effectively save energy is important to be able to include dynamic simulations into the scenarios assessing the energy efficiency of selected measures.
Although it is out of the scope of this work, the energy behaviour manager can also have the important role of raising awareness among occupants in the office buildings he/she works, since user behaviour is an issue to be investigated and tackled not only at household level, but also in the work environment.

Pros	Cons
New skills to public and private actors to properly manage the impact of occupant behaviour at organisational level Complementary to the energy manager expertise, making the measures to save energy more effective.	Lack of skills to properly address this role.

PS10 | Sustainable behaviour coach

Actors to be involved

- Public housing providers
- Tenants

Main features

The sustainable behaviour coach is a new professional figure that should be integrated in the public housing provider staff to support behavioural change with a very pragmatic approach. He/she should be coordinated by the energy behaviour manager (PS09) in order to facilitate the communication with tenants to help households not only to achieve the overall behavioural campaign targets, but mostly to set their own targets to change behaviour and normalising it.

Coaching programmes can be phone or social media-based services aimed at intensifying participation in energy conservation, for normalising behaviour, and forming a basis of social marketing strategies.

Among the sustainable behaviour coach responsibilities, there are:

- identifying the barriers to engage households into sustainable behaviours through focus groups, online discussion boards and surveys;
- designing a strategic approach that integrates behaviour change tools, appropriate messaging and graphics;
- launching media advertising, promotions, announcement letter, to make explicit the willing of the public housing providers to commit to the programme. Lack of trust is a tangible barrier in Italian public housing stock (Santangelo and Tondelli 2017c);
- delivering educational materials, which should be brief and easy to understand;
- designing and delivering feedback/progress letters followed by coaching phone calls whenever necessary.

Pros	Cons
He/she will be the main referee for the tenants in the behaviour change campaign, supporting the public housing associations to provide an effective service.	Lack of trust: pro-environmental behaviour is likely to be considered if information and education measures come from credible, trustworthy sources.

5.3. Description of benefits

According to the International Energy Agency, energy efficiency can be referred as the hidden fuel, since it is measured as a negative value (i.e. the energy not consumed or energy cost saved), and its benefits are to some extent intangible, threatened by uncertainties related to consumer behaviour (OECD/IEA 2014). Energy efficiency investments are mainly driven by the need of lowering energy demand and delivering energy cost savings. However, evidence from research is increasingly demonstrating that reducing energy costs and demand are only two among the multiple benefits that such investments can introduce. Some co-benefits may even deliver two or three times more value than the energy demand reduction (OECD/IEA 2014).

Although energy efficiency experts and policy-makers are aware to a certain degree that improving energy efficiency generates broader impact than cost savings and reduced environmental impact, they are certainly not fully aware of the household behaviour impact on energy building consumption, whether the housing stock is energy efficient or not. Hence, this section focuses on the description of multiple benefits that can be delivered through the introduction of the proposed solutions in section 4.4.2, to tackle consumer behaviour awareness and behaviour change campaigns. Some of them are more tangible and easier to assess than others, in particular the social benefits, which are more likely to be only qualitative quantified. They are classified in Figure 5.5.

The *energy system benefits* are the ones related to the energy system characteristics in terms of energy production, distribution and consumption. Raising awareness among consumers, providing information and improving professional skills can facilitate the effectiveness of energy efficiency improvements in delivering the expected benefits. In fact, without tackling consumer behaviour, reduced energy demand cannot be ensured due to the rebound effect (Haas et al. 1998; Jenkins et al. 2011; Guerra-Santin 2013; Ben and Steemers 2014; Guerassimoff and Thomas 2015; Santangelo and Tondelli 2017a), therefore resulting in exposing energy security and reduced peak loads at risk. Tackling energy behaviour while improving energy efficiency in housing sector can improve energy security in terms of fuel availability, accessibility, affordability ad acceptability (OECD/IEA 2014).

To help consumers to lower their energy consumption, with clear billing information and smart energy meters, is one of the five long-term measures promoted by the European Commission Energy Security Strategy released in 2014 (European Commission 2014). Other benefits as avoided new generation capacity and energy delivery, respectively identified by BPIE (2013) and OECD/IEA (2014) have been here included in the energy security benefit.

Reduced peak loads is another positive consequence of improving energy awareness among households and delivering feedback towards behaviour change. Measures reducing energy demand save a disproportionate amount at times of high demand (i.e. through reduced winter heating and summer cooling) (BPIE 2013).

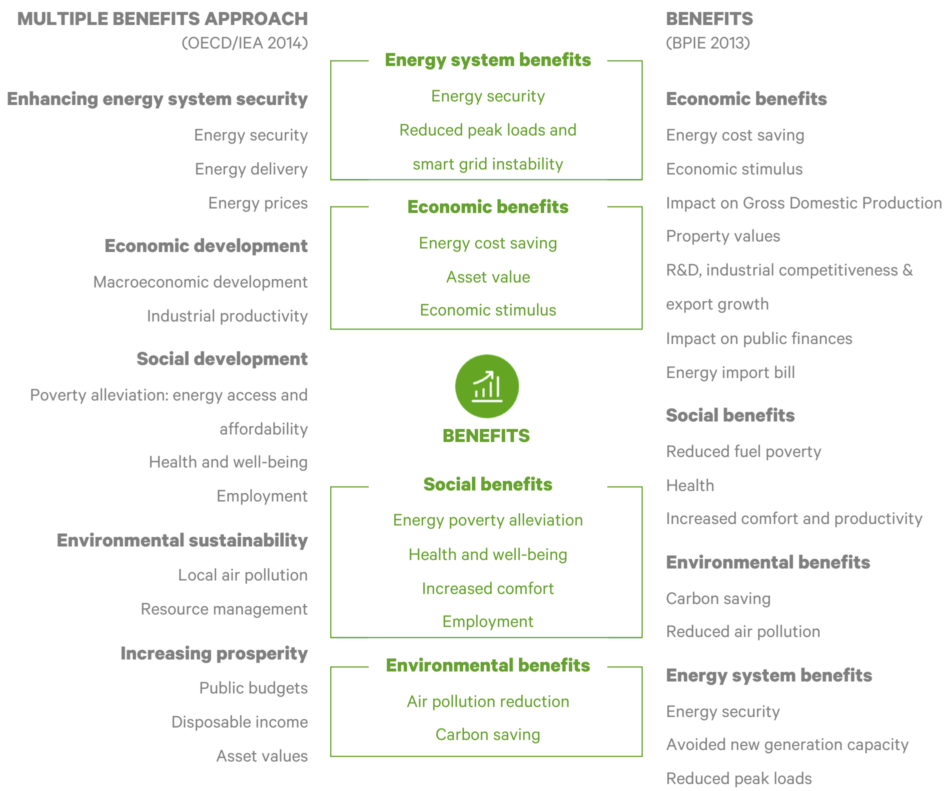


Figure 5.5. Classification of consumer behaviour strategy multiple benefits. Source: author's elaboration.

Smart grid stability is affected by consumer behaviour and the information available to act (Juelsgaard et al. 2013). To actively involve users and stakeholders in smart grid projects has been demonstrated to have positive effects towards the implementation of a low-carbon economy (Verbong et al. 2013).
Economic benefits, in particular energy cost savings due to reduced energy demand and lower energy consumption, are the most evident results of energy efficiency measures addressing consumer behaviour. Behaviour change can lead to the effective implementation of deep renovation scenarios, estimated by BPIE analysis (BPIE 2011) in 1,300 billion euro (present value) of energy cost savings. New professional skills can also deliver energy efficient measures to increase the building asset value and to reduce the maintenance costs, which represents one of the highest concerns for public housing providers.
More efficient building energy performance has also consequences for the market value for private buildings, and for the social and economic value for public building stock. Addressing consumer behaviour in building renovation process will also be an economic stimulus, resulting in an increase of the total investment for

energy efficiency through new jobs and new skills development. Macroeconomic development, industrial productivity, public budgets (OECD/IEA 2014), and impact on GDP, impact on public finances, R&D, industrial competitiveness and export growth, and energy import bill (BPIE 2013) also fall into the economic benefits category.

When it comes to the public housing stock, energy poverty alleviation is one of the most important *social benefits* of increasing energy efficiency towards reducing energy consumption. Improving the energy efficiency of homes has been recognised as vital to achieve energy affordability for low-income households (BPIE 2013). The provision of information and feedback can lead to behaviour changes, which are fundamental to achieve building deep renovation and to reduce energy bills. In fact, in both developed and developing countries, the low-income households are more likely to live in inefficient housing stock and less able to afford the up-front cost of energy efficiency goods and services, thus, facing higher energy costs than others (OECD/IEA 2014).

Health and well-being benefits resulting from the improvement of indoor environment, as a consequence of implementing energy efficiency measures, are consistently strongest among vulnerable groups (OECD/IEA 2014). Health benefits from energy retrofits could be worth more than the value of energy savings. A case study in New Zeeland has demonstrated that programmes for energy efficiency retrofitting of low-income housing can deliver the greatest benefits, with health improvements representing as much as 75% of the total return on the investment for these interventions (Grimes et al. 2011).

Increased comfort is also a social benefit. However, it can also turn to higher energy consumption than expected if no awareness programmes are coupled with energy retrofit one. Investments in energy efficiency and behaviour change campaigns can also lead to an increase in employment rates both directly and indirectly (i.e., through an expenditure shift effect) (OECD/IEA 2014), generating a variety of social benefits in addition to the economic ones. The increase of disposable income (OECD/IEA 2014) is also grouped among the social benefits.

Lastly, consumer behaviour is one of the responsible factors of delivering *environmental benefits* such as reduction of air pollution and carbon emission reduction, resulting in environmental improvements only possible if supported by pro-environmental behaviours.

5.4. Beyond public housing: recommendations for the residential sector as a whole

Despite the limited size of the Italian public housing stock, it has been investigated in this research due to the following favourable conditions:

- the housing is publicly owned by either the municipalities, or the housing providers, while the latter have an exclusive role in public housing stock management. Therefore, decisions about renovation requires to come to an agreement between a very limited number of actors;

- public housing stock is owned by local authorities, while the regulation on this sector is a regional subject, and, across Italy, regional regulations and managing and allocation procedures among housing providers are similar, resulting in a high replication potential;
- multi-dwelling building is a building typology representative not only for the Italian public residential stock, but also for the whole Italian housing sector, therefore, the simulation results provided in Chapter 3 can be considered exploitable also for the private sector;
- while in the owner-occupied sector cost-savings are expected to be the main stimulus for building energy-efficient renovation, the interventions within the public housing stock not only have an energy-saving value, but also contribute to achieve social and economic co-benefits, to avoid stigmatisation, social segregation and to mitigate energy poverty.

Nevertheless, consumer behaviour is certainly not only an issue for the social housing sector. Household income has proven to be an important factor in determining energy use (see Chapter 2), but scholars investigating the determinants of consumer behaviour have found controversial results on the income as a behaviour determinant (Guerra-Santin et al. 2009; Romero et al. 2013; Wei et al. 2014; Schaffrin and Reibling 2015). Therefore, user behaviour is worth to be investigated in the social housing sector as well as in the private one, regardless the housing tenure and the public or private nature of the housing landlords. Several studies on occupant behaviour and energy consumption have been conducted in the social housing stock, due to either the size of the sector within the national context (Gupta and Chandiwala 2010; Crilly et al. 2012; Huebner et al. 2013; Brown et al. 2014; Hayles and Dean 2015; Guerra-Santin et al. 2016), or specific renovation programme opportunities (Elsharkawy and Rutherford 2015; Jones et al. 2017; DellaValle et al. 2018). However, none of them concluded that the focus on social housing has represented a limitation to the soundness of the results. On the contrary, the focus on social housing has been found to be beneficial to test a methodology to identify a range of context-specific variables that can be then used as levers to align behaviour to retrofit interventions (DellaValle et al. 2018).

In this section, considerations on how to embed energy behaviour in current policy instruments are, therefore, extended to the Italian residential sector. As framed in Chapter 1, the European Commission has no right to regulate spatial planning, since it is a subject directly managed at Member State level. However, consumer behaviour is a topic which has started to gain increasing attention at the European level, and energy policies and directives have recognised the role of human factor in achieving energy savings in the building sector. Therefore, the main recommendation is to contribute by adopting a practical approach, directly promoting activities aimed at engaging citizens in saving energy through behaviour, raising awareness among the role of behaviour to effectively implement energy efficiency, and creating a strong network of actors operating in this field. The "Behaviour Change Challenge" could be a proposal for new measures to implement. Similar initiatives have already been promoted at EU level in the field of mobility, as, for instance, the European Cycling Challenge[2], which has been a successful competition since 2012 among European cities, won by the city which runs by bike the longest distance thanks to the registered users activating the GPS during their rides. The "Behaviour Change Challenge" could similarly operate on yearly basis by engaging households in providing information on their current energy consumption and behaviour, to be compared either with data on energy consumption of the previous year, or through benchmarking with users living in dwellings with similar characteristics. Energy savings due to behaviour should be normalised taking into consideration the different climate conditions of EU regions. Within the same cities, teams could be created aimed at engaging the users at community level in addition to the individual level. Indeed, the commitment at community level is expected to last longer than the lifetime of the EU public campaign, resulting in delivering long-lasting benefits.

At the Italian national level, the main recommendation is to rethink the current tax deduction scheme by including considerations on user behaviour. At present, taxpayers paying personal or business income taxes are entitled to claim back certain percentages of total building renovation costs, according to the type of interventions and degree of energy efficiency implemented. On the contrary, in the new recommended scenario, incentives are influenced by the willing of citizens to opt in an occupant behaviour change programme. They are not distributed anymore according to the saving potential of renovation measures installed, but according to the effective energy consumption, through data and behaviour analysis, where pre- and post-renovation occupancy evaluations should be performed to build the framework for assessing the energy savings. Different percentages of incentives can be associated to different abilities to reduce the gap between expected and actual energy consumption.
In addition, private actors such as energy utilities, which own an enormous amount of data, today mostly used for marketing uses only, should be increasingly forced to promote social aims, such as tackling energy poverty through initiatives addressing behaviour. In the framework of the Italian Energy Efficiency Obligation Schemes, implementing Article 7 of Directive 2012/27/EU on Energy Efficiency (MISE 2013), energy companies having more than 50,000 end users have the obligation to generate each year a certain amount of savings or, alternatively, to purchase an equivalent amount of White Certificates[3]. However, the only measures included towards energy savings through behaviour awareness and change are specific incentives for energy

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2 http://www.cyclingchallenge.eu/.

3 White certificates, also known as energy efficiency securities, are tradable securities certifying the achievement of energy savings in the final uses of energy through energy efficiency measures and projects. The white certificates mechanism is based on the creation of an obligated market for these certificates. The obligation scheme was introduced by the legislative decrees that liberalised the electricity and the natural gas markets (Ministerial Decrees of 20 July 2004), placing Italy at the forefront in Europe and worldwide and yielding positive results over time especially in terms of cost/effectiveness (MISE 2013).

audit and energy certification, as these are currently considered to be important awareness-raising tools able to drive household choices and daily behaviour. On the contrary, other EU countries (i.e. UK, France, Ireland, Austria and Greece) have chosen to adopt a more far-seeing approach in their Energy Efficiency Obligation Schemes, including specific provisions with a social aim that can be either incentives or mandatory actions addressed to households meeting eligibility criteria (e.g. social housing tenants living in E to G energy class, households meeting certain income level) (Atee 2017). Utilities have potentially at their disposal the necessary data and means to identify energy poverty among their clients and effectively address it by fulfilling in this way the energy efficiency obligation. The way in which energy company relationships with their customers are changing is relevant to the future of this kind of policy (Fawcett et al. 2018). Therefore, the main recommendation for Italy is to does not miss the opportunity to persuade the obligated parties to contribute more and more to the social aim of energy efficiency by addressing occupant behaviour.

At regional level, funding schemes are usually subject to the compliance of local initiatives with regional goals. In the field of urban regeneration and energy efficiency, funds – or additional funds – might be distributed to municipalities which commit themselves to implement activities towards behaviour change, and to sign agreements with public and private actors aimed at engaging citizens in behaviour awareness initiatives. When it comes to private actors – either ESCos, private building managers representing several homeowners, or private landlords – who seek to improve the energy performance of the existing building stock, implementing some of the proposed measures for public housing (see section 5.2) as, for instance, PS07 Energy behaviour quiz and PS08 Informative energy bill, could lead to an extra score to receive financial or non-financial incentives. In fact, both public and private initiatives which contribute to increase behaviour awareness of citizens and to collect information and data to improve energy household consumption and behaviour should be encouraged with tangible rewards. The Italian Regions could, therefore, contribute to this aim by allocating part of the European Regional Development Funds to initiatives addressing behaviour, and, even more important, working to strongly embed this issue into the regional policy instrument for the next programming period. When it comes to urban planning regional regulation, as framed in Chapter 1 for the Emilia-Romagna Region, to promote urban regeneration and to enhance the urban and built environment quality are already among the most ambitious goals of the regional legislation. To pursue these objectives by prioritising planning strategies able to embed the human factor, in addition to technology, could lead to a disruptive social innovation change, which is what urban regeneration process might need to move from being an opportunity to be the solution.
In this framework, the LR 24/2017 Emilia-Romagna Regional legislation on the territory protection and use, just entered into force at the beginning of 2018, can provide new opportunities. Indeed, it innovates the traditional methods for both planning and implementing territorial transformations, and it foresees a flexible

and negotiated urban regeneration model based on densification, demolition and reconstruction, aimed at improving the performance of buildings and at the simultaneous redesign of open spaces, with the goal of raising the resilience of the city. Such transformations require new models and integrated tools for planning, implementation, management and monitoring of regenerative interventions, able to integrate the interventions in a dynamic and evolving urban context. Law n.24/17 explicitly requires the municipalities to build the regeneration strategies for their territories basing on an accurate analysis of the state of the art, focusing in particular on seismic safety and energy performances of the buildings. Information and dataset on actual energy consumption and household behaviour would, therefore, improve the analysis of the state of the art (i.e., *quadro conoscitivo*) for what concerns energy efficiency, enriching the understanding about the current situation and helping in prioritising the regenerative measures.

Coming to the local level, the main recommendation is to embed household behaviour into urban planning tools, to contribute to make energy efficiency goal more horizontal and central, rather than a side effect. Scholars have argued that, for being successful, the challenge of planning tools and regulations is not only to address GHG emission control and energy savings in buildings, but also to promote energy efficiency as a cross-cutting and integrated issue addressing all the relevant aspects of sustainable urban development (Conticelli et al. 2017). When it comes to the Bologna case study (Table 4.3), the General Urban Plan *(Piano Urbanistico Generale – PUG)*, and the Operational Agreements between the local authorities and private parties in order to define the characteristics of each development, should focus on building seismic and energy performances as the key issues to be addressed by urban regeneration. The General Urban Plan (PUG) is the main plan establishing the municipal competences on territorial use and transformation, specifically focusing on urban regeneration and land-use reduction. Information on user behaviour and data on actual energy consumption could be aimed at improving the analysis of the state of the art for what concerns energy efficiency, enriching the understanding about the state of the art and helping in prioritising the regenerative measures. Among the elements which are imbedded in the PUG, the Strategy for Urban and Ecological-Environmental Quality is aimed at setting performance indicators and sustainability requirements to which interventions should be compliant with. It also identifies and spatially localised the actions that are needed to the strategy objectives. It could therefore benefit of a deepen knowledge on users' behaviour so to be able to set targets and to define incentives basing on the actual consumes thus making the urban strategies more effective.

Indeed, as the results of this work have shown, incentives in exchange for higher environmental performances, already foreseen in the legislation, should be calculated on actual consumption, rather than predicted one, to be more effective and to better reflect the actual target that the local administration wants to pursue. The increased knowledge coming from actual energy consumption data

Table 4.3. Recommendations to embed behaviour into urban planning tools. The Bologna case study. Source: author's elaboration.

Planning tools	Main objectives	Recommendations to embed behaviour
General Urban Plan *(Piano Urbanistico Generale - PUG)*	It establishes the municipal competences on territorial use and transformation, with a focus on urban regeneration of existing assets.	Information on user behaviour and data on actual energy consumption would improve the framework for the state of the art *(quadro conoscitivo)* for what concerns energy efficiency, enriching the understanding about the state of the art and helping in prioritising the regenerative measures.
Strategy for urban and ecological-environmental quality *(Strategia per la qualità urbana ed ecologico ambientale)*	The strategy is part of the PUG. It is aimed at set performance indicators and sustainability requirements to which interventions should be compliant with. It also identifies and spatially localised the actions that are needed to implement the strategy objectives.	Engaging households in delivering energy savings could be among the actions that allow to reach the performance levels set by the strategy. The non-implementation of actions addressing behaviour should be also considered in the monitoring framework, to avoid overestimating the results of energy efficiency measures.
Operational agreements (Accordi Operativi)	They specify the transformations and new developments foreseen in the PUG. They are the results of agreements on the implementation of urban transformations between public and private partnerships.	Incentives in terms of reduction of construction burden, or other form of bonuses could be foreseen for private developers who include deprived and low efficient built areas to their scope of actions. Public lump sums could be also delivered to private developers to launch the behaviour awareness campaign as an integral part of urban regeneration projects. Fiscal/economic incentives to private citizens could be conditioned to their availability to opt in a behavioural awareness campaign at municipal level.

and behaviour patterns should be used to drive the urban regeneration strategies, promoting transformations in some portion of the existing city more problematic than others, to reach an energy balance at neighbourhood or district level over the long term.

Engaging households in delivering energy savings is an action that could allow to reach the performance levels set by the strategy. Moreover, the non-implementation of actions addressing behaviour should be also considered in the monitoring framework, to avoid overestimating the results of energy efficiency measures.

In the framework of the LR 24/20017, the Operational Agreements are specific tools that complement the PUG. They are aimed at further specify the transformations and new developments foreseen in the PUG, as results of agreements on the implementation of urban transformations between public and private partnerships. Recommendations to embed into the operational agreements considerations on behaviour can take different forms. Incentives in terms of reduction of construction burden, or other sort of bonuses could be foreseen for private developers who develop behaviour awareness campaign within deprived and low efficient built areas. In addition, public lump sums could be also delivered to private developers to launch the behaviour awareness campaign as an integral part of urban regeneration projects. Moreover, fiscal/economic incentives to private citizens could be conditioned to their availability to opt in a behavioural awareness campaign at municipal level. Indeed, when it comes to the role of homeowners, the research results may suggest that fiscal incentives to implement energy efficiency measures should be given only to citizens available to sign an Energy Performance Contract (EPC) for a certain timeframe with the Municipality. By signing the EPC, the individuals commit themselves to participate to a behaviour awareness campaign, to let energy utilities or ESCos monitoring their energy consumption, to reach certain energy saving targets, and to pay an extra cost in case the energy performance is disattended.

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››› Conclusions

Embedding energy considerations into spatial and urban planning allows to build the strategic and operative framework where both mitigation and adaptation measures can be positioned in the broader perspective of sustainable development. To achieve energy reduction targets, energy efficiency measures should be conceived as a part of an integrated urban strategy fostering a comprehensive urban regeneration of the existing city. Indeed, the local authorities have a key strategic role in coordinating and driving the activities of a range of actors, in defining target areas and communities to focus on, and in engaging people in adopting sustainable behaviours, to make the measures effective.

The overall aim of this publication has been to understand the linkage and reciprocal contribution of urban regeneration and energy renovation of residential buildings. The research specific contribution has been to show the relevance, the urgency and the feasibility of improving energy policy instruments to take into account consumer behaviour, and to provide new solutions to local authorities, public housing associations, energy companies and all the stakeholders taking part to the building renovation process. The goal has been to show, on the one hand, the relevance of the occupant behaviour, at present seldomly included in the consideration of the measures to renovate the buildings; on the other hand, the relationship among stakeholders involved in the renovation process, in order to suggest improvements to increase the process effectiveness.

The research focus has been on the Italian context, where energy efficiency through building renovation and urban regeneration is a major challenge, and where building renovation can be considered as one of the strategies to achieve the regeneration of cities. This work has been aimed at demonstrating to what extent understanding the impact of the human factor on energy efficiency can enhance the effectiveness of housing renovation policies. This requires long term involvement of all stakeholders, including the final users, in developing policy, measures, technologies, and monitoring schemes.

Public housing, social housing and housing policies have always been studied by urban planning as ways to achieve sustainability in cities. Demonstrating, prior in public housing stock than in the rest of the housing stock, the interrelation among stakeholders to implement energy renovation, and the relevance of household energy behaviour to effectively reduce energy consumption in buildings, could lead to a multiplier effect.

The problems and limitations framed in this work make explicit the urgency to tackle household energy behaviour as a prominent issue to effectively achieve building renovation and energy savings. Many disciplines have already contributed to suggest how to better incorporate the human factor in their core research topics. In fact, the gap between expected and actual energy consumption, together with the impact of occupant behaviour on building energy use, have been increasingly studied by scholars, who contributed to demonstrate that energy savings through behavioural factors can be as high as those from technological ones. Therefore, the occupants have the possibility either to reinforce the savings from energy efficiency measures, or to waste them. This research has provided an additional contribution from the urban planning perspective.
Key findings are summarised below, grouped according to the main topics investigated throughout the research.

Framing consumer behaviour in urban and energy planning

Consumer behaviour is rather complex, interrelated with many factors, some intrinsic to the individuals, others that depend on the building characteristics and more generally on the local environment where people live. Two main approaches to capture consumer behaviour have been identified, namely the social science approach and technological and engineering-based one. They have been broadly investigated to understand how different disciplines have contributed to the topic, and where insights from urban planning could increase knowledge on the topic.
However, the difficulty to quantify behaviour has also represented a limit the integration of the human factor in energy efficiency policies and building renovation strategies, with a consequent overconfidence in technology. Energy efficiency has been recognised as a multiscale issue, addressed by several policies and regulations. It concerns every governance level and it involves multiple stakeholders. However, the investigation conducted has confirmed that there is a general tendency both in legislation and strategies to focus on the building scale, rather than the urban scale. The majority of research on consumer behaviour focuses on single buildings, rather than on the urban scale. Inappropriate choice of occupant behaviour model could result in oversized district energy systems, leading to over-investment and low operational efficiency. Future research should aim at assessing the impact of occupant behaviour on a larger scale, considering urban regeneration as the ultimate goal.
At the same time, urban planning is still not much driven by energy planning, which in turn does not pay enough attention to the territorial level. An insight into the policy framework and regulations elaborated at four levels of territorial governance (i.e. international and EU; national; regional; local) is provided, to verify to what extent consumer behaviour, building renovation and urgency to take actions on public buildings are embedded in the energy and sustainable

development policies. Consumer behaviour and awareness on behaviour impact are key issues currently somehow embedded in EU Directives, since they are mentioned when it comes to smart meters and new way to deal with the energy market (i.e., from consumer to prosumer). However, the implementation of measures to support behaviour change and to build community awareness are left to the Member States, with neither indication on possible ways to achieve the goal, nor recognition that urban planning tools could contribute to deliver such behavioural change.

When it comes to the renovation of the existing stock, the analysis has shown that policy-makers are currently facing the challenge to design and implement effective housing renovation strategies both for the public and the private housing stock, able to support not only the technical and physical renovation, but also a change of paradigm in energy consumption. Policies and regulations at different territorial levels are struggling to encourage decisionmakers to include information to users as a prerequisite to implement effective energy efficiency strategies and to lower energy consumption.

For what concerns spatial planning, it emerged that in none of the investigated levels energy is truly integrated. At the local level, the urban planning tools are still not enough driven by energy planning. The energy issue is generally embedded in terms of performance and reduction of energy demand in buildings, while the role of building occupants in achieving such goals and the relationships between behaviour and building characteristics are completely neglected.

Energy efficiency is considered to be a technology-driven issue, rather than a matter of behaviour and consumption patterns. Spatial planning is either a national or a regional legislation subject, depending on the Member States administrative characteristics and regulation, therefore, should not surprise that it is barely mentioned in international strategies and EU energy Directives. However, the absence of measures and actions related to the design and use of territory within the Italian policy instruments has been identified as a weakness element.

The urban scale has turned to be the most suitable level where all different renewal-oriented tools could be applied together, and the positive effects of incentives and rewards mechanisms could be multiplied. This would also allow the implementation of new and more collaborative approaches involving the public sector, occupants, households and developers acting in the building sector, driving the transition towards a credible and long-lasting model of low-carbon city. Investigating consumer behaviour in the framework of urban planning can provide an insight into the urban regenerative potential of cities, which relies, among others: on the one hand, on energy awareness of people, their behaviour, capacity and willingness to adapt; on the other hand, on the ability of public authorities to design renovation strategies to turn occupants into active actors, rather than passive target groups.

Household behaviour determinants and strategies to promote behavioural change

Among the main key factors determining energy behaviour, there are both household characteristics and building characteristics. In particular, results show that household behaviour can be influenced by: demographic factors as gender, age, household type and size, health; educational factors as level of education, awareness, knowledge, motivation; socio-economic factors as housing tenure, income, cultural background, occupation. Among building characteristics, there are: external factors such as outdoor air temperature, wind speed and direction, horizontal global irradiance, air pollution and noise; and internal factors such as building envelope and type of windows, dwelling size, mechanical systems and appliances.
Many different energy-related behaviours in the building sector have been investigated so far, with the heating pattern as the most studied. Future investigations about the interrelationship between different energy behaviours are needed, which will generate more realistic assumptions in building energy performance. For being able to address the complexity of the human factor in energy consumption, the social effects, technical characteristics and building performance simulation models, the role of economic, taxes and incentives as well as the policy instruments should be further investigated in combination one with each other. Any single discipline will provide a limited view of the topic at most. Interdisciplinary studies are required to get a more comprehensive understanding on ways to regenerate cities and face the climate change.
Results have shown that physical renovation of buildings should be integrated by the information and training on sustainable occupant behaviour, especially in the case of housing stock where low-income people are accommodated, in order to ensure both environmental and social sustainability of the interventions. Energy can be considered as a driver to urban regeneration, while addressing attitudes and behaviour change is a prerequisite for co-creating and co-implementing regeneration strategies. As result of literature review, some key elements for successful behaviour change initiatives have been identified and presented.
In order to change the consumer behaviour, the tools adopted can be divided in two main groups: disincentive and incentives through laws and regulations, and informative tools for increasing occupant knowledge and awareness. Both approaches require effective policy instruments to support all the stakeholders involved in the implementation of energy efficiency measures to deliver such change. Indeed, the role of policy instruments for energy efficiency should be further studied in order to effectively address the behavioural patterns of different user groups.
Future research should focus on the definition of user profiles to design different policy instruments able to address different consumption lifestyles. However, in the social housing sector where public resources and private investments are particularly scarce, some simplification strategies and an "express methodology" may be necessary to define the user profiles.

Urban planning is one of the disciplines that has recently started to focus on the human factor as a driver for the effective implementation of urban renovation programs. Understanding and tackling user behaviour by embedding renovation measures and incentives to lead to behaviour change in urban planning tools could contribute to bridge the gap between the provision of energy efficiency measures in policy and regulations and their actual implementation.

Results from the investigation of the impact of behaviour on household energy consumption

The results of the investigations conducted in Chapter 3 have reinforced two discourses: on the one hand, around the need of building a robust framework for data collection and processing on energy behaviour and household preferences and practices; on the other hand, around the need to adopt complementary approaches to reduce energy consumption, since physical improvements and behavioural changes have shown different impact on energy savings that need to be addressed at the same time.

At first, results from the statistical analysis have contributed to demonstrate that the use of statistics to determine the household characteristics related to energy use in buildings is a powerful tool to investigate the relationship between energy behaviour and household characteristics. In the specific case of Italian statistical, three variables – thermostat, household composition and working condition – have resulted to be statistically significant in affecting the use of the heating system. However, many gaps in the dataset have emerged, and a greater effort must be put in place by public authorities and other public or private institutions participating to collect data, to enable scholars to contribute to the energy behaviour topic.

Secondly, the use of a building performance simulation tool to investigate the impact of behaviour and to build scenarios to inform decision-makers has been illustrated. Besides this tool is usually applied by scholars dealing with the design of new buildings and the need to simulate behaviour patterns prior to the occupancy phase, in the case of this research, this approach has resulted in an increased understanding of the role of occupant behaviour to improve the effectiveness of renovation strategies, particularly relevant for policy-makers which are always struggling with the lack of resources and have to choose to invest on the most promising measures. Results provide estimation of the gap between expected and actual energy savings due to the human factor. They explain the impact of rebound effect in case of building retrofit, as well as the impact of "green behaviour" when positive behavioural changes occur. The findings suggest that, while the occupant behaviour influences the heating loads up to 1/3 in case of high level of building retrofit, the less the building is renovated, the more is the behavioural impact in absolute terms of energy reduction.

Finally, a methodology based on multi-criteria assessment of different strategies has been presented. Based on AHP, it has been designed to explicitly incorporates the impact of user behaviour into the assessment of planning strategies and renovation measures. Four criteria and seven measures have been identified. Results show that the measures relying on user behaviour more than others, have resulted to be the top alternatives by three out of four criteria. To address behaviour should be intended as complementary to other structural measures, and first to implement to raise awareness and drive behaviour towards more energy sustainable practices. Moreover, technologies should be only one aspects of a complex system where spatial organization, consumer behaviour and technologies interact with each other, determining the actual and future pattern of energy consumption. Better integrated complementary approaches to both the technical and social energy transitions are required.

The role of public housing sector in showcasing the benefits of addressing behaviour

Despite the limited size of the Italian public housing stock, due to the favourable situation of public housing providers having an exclusive role in public housing stock management, and the similarities in the regional regulations and procedures among providers, the public housing sector has been selected as a case study for this research.

The analysis conducted has identified the main characteristics of the Italian public housing sector, the interrelation among actors operating in the renovation of the public housing stock, and the contribution that the understanding of the human factor can give to alleviate energy poverty. The institutional framework concerning housing and urban regeneration is nowadays more fragmented, involving more actors than in the past, both for-profit and non-profit. The role of the government is becoming less prominent, while the influence of market actors and civil society organisations is increasing. Five main categories of actors have been identified, where the community and the residents are intended as one of the active actors, rather than passive target groups.

The extreme fragmentation of housing demand, the increasing energy poverty of tenants living in public buildings, the overall decline of public spending on the housing sector, and the ongoing redefinition of the role of public authorities are only some of the elements describing the Italian housing issue. New conceptual and methodological advancements are needed in order to tackle the housing issue, both from the point of view of scholars and of decision-makers, where the provision of information, awareness raising and new skills can be the driver not only for the renovation of the public housing stock, but also for a new housing policy based on providing housing as a services, rather than just an asset.

Finally, embedding behaviour strategies into renovation programmes of the public housing stock might be a fundamental step forward to tackle energy poverty and energy vulnerability, particularly prevalent in the public and social housing sector. Engaging occupants into activities to raise awareness on the impact of their daily practices might led to achieve other co-benefits, rather than the optimisation of energy consumption, with a positive impact on social inclusion. Energy poverty policies should embed household behaviour in their considerations as a driver to alleviate the energy poverty conditions, in particular in absence or scarcity of structural policies.

Proposals for addressing energy behaviour through policy and planning instruments

The focus on the Italian public housing sector in terms of actors involved, barriers to the implementation of the building stock renovation, and the identification of drivers to overcome them has been investigated. No one-size-fits-all solution is possible due to peculiarities across household and building characteristics. Therefore, several measures are suggested to demonstrate how household behaviour can be embedded in the policy instruments and tools currently in place through the description of practical solutions. Benefits of accommodating consumer behaviour into policy instruments have also been highlighted.

Recommendations to deliver such measures addressing behaviour awareness and information to households of the private residential sector, including homeowners and other tenants from the private sector, have also been presented. They have been aimed at showing the replicability potential of a new governance targeting environmental awareness, rather than just technical implementation of energy efficiency measures, and the planning instruments to work on in order to deliver such change. A focus on the local planning tools of the City of Bologna has been considered, to further specify how and where behaviour should be embedded to achieve a better understanding on the role of energy efficiency for urban regeneration.

A major driver behind energy efficiency investments is the capacity to lower energy demand and to deliver energy cost savings. While energy efficiency experts and, to some extent policy-makers, are aware that energy efficiency generates broader impacts than the ones usually captured by the monitoring framework, these impacts have not been systematically assessed. To better inform the policy decision-making process, further research should focus on the development of more robust methods for measuring multiple benefits, so that the important social and economic co-benefits might be better integrated into energy policy instruments.

The availability of energy data and information on behaviour and attitude towards energy efficiency has been found to be a strategic component for investigating occupant behaviour and behaviour change. It has emerged throughout the book, and it has been one of the main limitations. Therefore, one of the most urgent proposed actions regards the setting of a residential building performance database to be combined with results from behavioural survey to be coordinated at national level. Building a knowledge baseline for the development of strategies and tools to renovate the housing stock, and for addressing the consumption behaviour impact on energy savings, constitutes the driver to show to private investors the high replication potential of implementing the regeneration of the existing cities. As long as data would be fragmented and co-benefits difficult to assess, the occasional interventions will not turn to a systematic approach. Being urban planning a discipline able to hold different interests and multiple territorial needs, it is expected to be a key contributor to manage the complexity of such change.

Limitations

The availability of energy data and information on behaviour and attitude towards energy efficiency has been found to be a strategic component for investigating occupant behaviour and behaviour change, and it has to be reported as one of the main limitations.

Microdata on energy consumption resulting from the reading of smart meters in the residential sector are owned by private companies, either energy utilities or ESCos. Besides the privacy concerns there are other reasons behind the difficulties in getting data for research purpose. While explaining those reasons is beyond the scope of this research, it should be noted that the informative nature of the data to deliver feedback to users is not commonly recognised. The energy utilities and service companies that own the data are mainly interested in increasing their profits, rather than supporting users to deliver changes towards energy savings and contributing to alleviate energy poverty. This role should be performed by the public authorities, which should not miss the opportunity to persuade the private parties to take their steps to contribute to deliver energy efficiency social benefits by addressing occupant behaviour.

The statistical dataset embedded a series of limitations that have been specified in Chapter 3. Limitations are related both to the issues excluded from the investigation, and to the unavailability of results for some variables, although the related questions were included in the survey. It has clearly emerged the need to improve the results by improving the questions and the issue addressed. Almost no questions were asked regarding reported behaviour, occupancy patterns and preferences. For instance, ventilation behaviour was totally absent from the survey, although it is recognised to be an important factor affecting the heating consumption in wintertime. Data on energy expenditures were so aggregated to be not usable in statistical tests. Future research should focus on how to make the tools for collecting information on occupant behaviour and energy consumption even more informative, towards standardised procedures easy to be applied. As soon as more accurate data become available, in particular for energy consumption, energy expenditures and behaviour, through statistics it would be possible to determine the occupancy patterns to pre-define the occupancy of a building when real information about the occupants is not available. This approach can represent a great opportunity for policy-makers and ESCos in case of building renovation, since the behaviour profiles can be integrated into the models for assessing the renovation process, resulting in a more accurate method to determine: on the one hand, the expected building performance accounting for household variation; on the other hand, the levers to be triggered in order to support household in delivering the expected savings.

Recommendations for future work

Throughout the book, different methods have been applied, depending on the data availability and the aim of the specific investigations. Even those methods and tools which are not commonly applied in urban planning studies, have turned out to be powerful sources to provide evidence of the impact of occupant behaviour on urban planning strategies.

By building on the research findings, further research in urban planning and other disciplines could contribute to increase the effectiveness of renovation measures, in terms of energy savings, economic feasibility and social acceptability. Future investigations about the interrelationship between different energy behaviours are also needed, which will generate more realistic assumptions on building energy performance.

For being able to address the complexity of the human factor in energy consumption, the social effects, technical characteristics, the building performance simulation models, the role of economic, taxes and incentives as well as the policy instruments should be further investigated in combination one with each other.

Integrating quantitative and qualitative approaches still remains an effort to be made in order to better understand behaviour determinants and the drivers for changing it. A higher integration would be also beneficial among different research fields, with many scholars advocating for more collaboration among different disciplines. Although some studies have already applied multi-disciplinary approaches, a greater effort should be taken in order to better understand determinants of behaviour, drivers to behavioural changes, and to what extent such changes can lead to urban regeneration.

Concluding, this research has provided novel knowledge on the relevance the impact of the human factor has on energy efficiency, and how this knowledge can be applied to enhance the effectiveness of housing renovation policies. The role of behavioural patterns of different user groups for implementing energy efficiency should be further studied in order to effectively include this new perspective into policy instruments and urban planning tools. Urban regeneration requires a deep understanding of the built environment and a strong engagement of citizens, who should be considered more and more as the catalyst factor of the regeneration process. Any single discipline investigating energy and occupant behaviour issues will provide a limited view of the topics at most. Interdisciplinary studies are required to get a more comprehensive understanding on effective ways to regenerate cities and to face the climate change.

Finito di stampare in Italia nel mese di gennaio 2023
per conto di Edifir-Edizioni Firenze

››› Energy efficiency has been recognised as a multiscale issue, addressed by several policies and regulations. It concerns every governance level, and it involves multiple stakeholders, especially in the residential sector. However, households are the ones who consume energy, not buildings as such, although at present they are seldomly included in the building renovation process.
The book focuses on understanding and tackling user behaviour to contribute to bridge the gap between the provision of energy efficiency measures in policy and regulations and their actual implementation.

››› **Angela Santangelo** is Junior Assistant Professor in Urban and Regional Planning at the Department of Architecture, Alma Mater Studiorum - University of Bologna. She has a background in architectural engineering and she holds a PhD in Architecture. Her main research and teaching interests include urban and rural regeneration, housing policy, resilience of cultural and natural heritage and energy behaviour-driven strategies.

ISBN 978-88-9280-150-9
9 788892 801509

€ 25,00