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# Renewable Energy Communities in Urban Areas: Determining Key Characteristics from an Analysis of European Case Studies

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**Abstract.** The European Green Deal aims to achieve neutrality in Europe by 2050. To do so, according to the European Commission, Renewable Energy Communities (REC) might be an attractive solution to find the right balance between sustainable and inclusive energy transition and security. Moreover, the central position of citizens as prosumers – instead of solely consumers – allows to reduce inequalities and to include the most vulnerable in the energy sector. This work aims at framing the key characteristics of REC in urban areas by analysing selected case studies located in large European cities (MeerEnergie-Amsterdam, EnerCit'If-Paris, Viertel Zwei-Vienna, Ecopower-Brussels, Energy and Solidarity Community East-Naples, Energent-Ghent, Hyperion-Athens) and to identify and analyse possible measures to be implemented in urban RES considering social, climate and technical impacts. The analysis is performed through a detailed factsheet built up considering the European Commission's energy transition recommendations, definitions and literature on REC. The collected information on case studies will then be clustered according to three main drivers (technical, climate and social) to make the key characteristics comparable and to understand the trends of each of them in the urban context. The results of this research allow for the identification of twelve measures, which may be considered to set up an urban renewable energy community.

**Keywords:** Renewable Energy Communities · cities · energy transition · case study analysis · stakeholder analysis · urban regeneration

# 1 Introduction

Today, one of the strongest interests at European level concerns the energy sector and its future composition. The double-knot link between mankind and energy has transformed society, pushing towards the need to cluster where there is easy accessibility and easy availability of energy. In force of that, over half of the world's population live nowadays in urban areas, with a further billion people expected to reside in cities by 2050 [1]. The demand for goods and services in urban areas is putting pressure on natural resources and the environment, contributing to a multitude of social and environmental problems such as climate change, biodiversity loss, air pollution, energy security and the overexploitation of natural resources.

Trying to mediate between the need for energy security and meeting climate targets, Europe is currently involved in a complete upgrade of its energy sector. Thanks to adverse political circumstances, such as international tensions over fuel retrievals, the EU is increasingly focused on boosting energy production through renewable energy sources. According to current statistics, the energy sector is responsible for more than 75% of the EU's GHG emissions [2].

Changing energy production from fossil to renewable solutions is necessary to meet the EU's energy and climate targets, which aim to reduce GHG emissions by at least 55% (compared to 1990) by 2030 and becoming a climate-neutral continent by 2050.

The EU response to this problem has been segmented in different types of intervention. One of the most interesting solutions in the EU is the creation of Renewable Energy Communities (REC), empowering the citizens and transform them from consumers in prosumer. REC create the possibility of auto-producing energy thus decreasing the dependency on fossil fuels to face a green energy transition. The dependency rate shows the extent to which an economy relies upon imports to meet its energy needs. It is measured by the share of net imports (imports - exports) in gross inland energy consumption (meaning the sum of energy produced and net imports). In the EU in 2020, the dependency rate was equal to 58%, which means that more than half of the EU's energy needs were met by net imports [3]. For this reason, the main pressure is to have most of the self-produced energy, as consequence of the autonomy prerogative that has always been present in the European Community. Of course, even if the main aim is to achieve energy security targets, the social component should be at the core of this technological revolution and deal with the social problems that are currently present in the territory. Energy poverty and energy justice should be as important as energy autonomy, as stated in Sustainable Development Goal number 7 "Affordable and clean energy" and the EU pillar of Social Rights principle 20 "Access to essential services" [4].

RECs are not a new phenomenon and they are receiving increasing

attention in the last years. The EU Green Deal and the current energy crisis are spurring calls for greater energy independence and measures to help individual households deal with spiking energy prices. Energy communities are one of the key elements for achieving the EU's energy transition. Development projections predict that by 2050, half of Europe's citizens could be producing up to half of the EU's renewable energy [5]. In 2019, the EU refitted its energy policy framework to help in moving away from fossil fuels towards cleaner energy and, more specifically, to deliver on the EU's Paris Agreement commitments for reducing GHG emissions. The development of RECs is influenced by spatial factors and several studies reflect upon the geographical differences that exist between them diffusion within Europe. In [6], they found that in earlier studies 18% of the studied energy communities were in a rural context, while only 2% were in an urban context. Renewables have the potential to play a key role in future urban energy systems. However, the rate of transition to clean energy sources in urban areas continues to be slow. Establishing REC in cities is more challenging than in rural areas because of the limited space available for energy generation and the more complex arrangements for the ownership of surfaces [7]. The various legal possibilities allow citizens, working with other market players, to team up and invest in energy assets. Such participation creates a more decarbonized and flexible energy system. Energy communities can act as a single entity and access all energy markets on equal terms with other market players.

According to the REDII and the recast of the EMD, there are currently two legal definitions of energy communities at the EU level: CEC (Citizen Energy Community) and REC (Renewable Energy Community).

Despite their differences, the two types of energy communities have major commonalities. They:

- Require a legal entity.
- Must be voluntary and open.
- Primary purpose is environmental, economic or social.
- Require a specific governance.
- For renewable energy communities (RECs):
- Proximity requirement of effective control (to be defined in national law).
- Limited membership (shareholders or members do not include large companies).
- Open to all sources of renewable energy (ex. Also heat), but renewable source only.
- Major purpose of enabling frameworks: to promote the development and growth of RECs to expand the share of renewable energy at national level.

In the design of an REC, the objective to be pursued turns out to be a mixture of more factors. From a technical point of view, this can pursue different ambitions, such as the optimization of production or the use of a

form of energy production designed for the project. Certainly, the technical areas must be contextualized in the available social landscape. The assessment of the stakeholders involved is substantial and must be laid at the basis of the design. An EC is based on the empowerment of citizens and the community at large. Therefore, in a similar context the stakeholders involved are different from a generic energy project. Other figures also come into play, which may not be included in the real EC, but which may determine its success or failure, such as external financiers or legal figures for approval or not (Table 1).

**Table 1.** Potential stakeholders involved in energy communities [8]

Stakeholder	Description
Initiator	Initiator of the EC who can be a private person, private entity or social enterprise/NGO
External Investor	Private person or entity/NGO who invests in the EC
Insurance Party	Private entity providing insurance services to the EC
Financing Party	Private person, private entity or public body providing financial support schemes
EC participant	EC member who can be a private person or private or public entity and a consumer or prosumer
Asset Owner	Private person or private or public entity owning an energy producing or regulating unit that is part of the EC system
Engineering Office	Private entity ensuring the technical set-up and maintenance of the EC
EC decision-making body	Private or public entity responsible for decision-making within the EC
Government	Public entity responsible for decision-making at higher levels
Legal Party	Private or public entity that supports the EC with legal support

The issue of energy production in cities has not developed as much as it was supposed to in the European context. The problems encountered in implementing an energy community project in a city context are varied and sometimes difficult to overcome. The main difference from the rural context is the absence of a large amount of renewable energy sources. Although, the rapid development of renewable technologies has led to the creation of types of mechanisms to use sun, water, wind, soil and waste to produce sustainable energy. The characteristics inherent in defining urban context undermine many of these possibilities. In fact, the urban area is characterized by a large population and buildings' density and a general lack of open green spaces. The objective of this work is to analyze the main trends, limitations and opportunities that may arise

in the creation of an energy community within the city context through a case study analysis and to identify a list of possible measures to be implemented in the development of a Renewable Energy Communities in urban context.

## 2 Material and Methods- Case Studies Analysis

Energy transition is currently one of the main aim cities are looking at and energy communities are a viable way of supplying energy self-produced and sustainable.

To further support the implementation of REC in urban areas this paper will follow two subsequent steps: i) selection and analysis of relevant case studies in European cities' context; ii) based on the case study analysis and on experts review, identification of social, technical and climate measures relevant to set up REC in urban areas.

### 2.1 Case Study Identification and Analysis

The case studies chosen are projects that have been or are being executed. This is intended to provide a practical understanding of possible interventions.

**Table 2.** Case Studio specifics (Name of the project, City, State)

1	MeerEnergie	Amsterdam	NE
2	EnerCit'lf	Paris	FR
3	Viertel Zwei, Wien Energie	Vienna	AT
4	Ecopower	Brussels	BE
5	Energy and Solidarity Community of East Naples	Naples	IT
6	Energent, living lab campus of Ghent University	Ghent	BE
7	Hyperion	Athens	EL

The analysis included the creation of a Fact Sheet, a basic template to find crucial information for the complete description of the activities. Fact Sheet (Table 3) is derived from a study of the possibilities of an energy community by crossing technical source (reported in correspondence), definitions of Renewable Energy Community and indicators for identifying the potential for effectiveness against energy poverty. In addition, the template has gradually adjusted to the information to be reported for

specific designs, self-compensating during the analysis or changing accordingly.

The information given in the Fact Sheets will be then processed to compare them. The analysis aims to highlight 3 Drivers present in the energy communities implemented in the city context.

**D1-Technological Driver:** The technological aspect is crucial to understand the applications of energy production, consumption and distribution techniques in city energy communities. The driver is divided into several subcategories, which aim to quantify, according to score, the attention of the project on several aspects. The scoring and the description of the subcategories are given in the following table.

**D2-Climate Driver:** The D2 wants to generate a practical assessment of the impact of energy community in the referred climate scenario. The assessment provides a set of additional information to those reported in the factsheet, including the climate and emission reduction targets of the city where the EC is implemented. The use of specific information makes it possible to understand how effective the EC is and useful for the specific municipality and for the specific production of GHG (expressed in CO<sub>2</sub> equivalent) per kWh typical of the country of origin. To assess against a common scale, indicators are expressed as a percentage.

**D3-Social Driver:** The D3 aims to assess the contribution that the energy community offers to the improvement of the social condition, the preferences and behavior of those involved and the influence it has in changing habits with a view to energy awareness. The evaluation therefore aims to understand how large the overall impact on the population is, attributing a weighting based on the factsheet information.

Through the analysis of case studies and several references related to the creation of the Factsheet (Table 3), the main measures to compare with for an energy community designed in an urban context were studied and identified.

## 3 Results and Discussion

### 3.1 Case Study Analysis

The sample covers 6 European countries (Netherlands, France, Austria, Belgium, Italy, Greece). In addition, the selected cities (Amsterdam [15], Paris [16], Vienna [17], Brussels [18], Ghent [19], Naples [20] and Athens [21]) have all presented their climate plan, defining the objectives and timing to achieve them. Indeed Paris, Brussels and Athens were like 3 of the winning “100 Climate-Neutral and Smart Cities by 2030” [22], so it is interesting to understand how they face the energy transition. The aim is to analyse 3 drivers: D1- Technical Driver, D2- Climate Driver, D3- Social Driver. As shown in Fig. 1 the values differ in the energy communities, highlighting diversities.

**Table 3.** Factsheet template, used for the 7 Case Studio. Concussion between the literature review and the case studio characteristics found during the analysis.

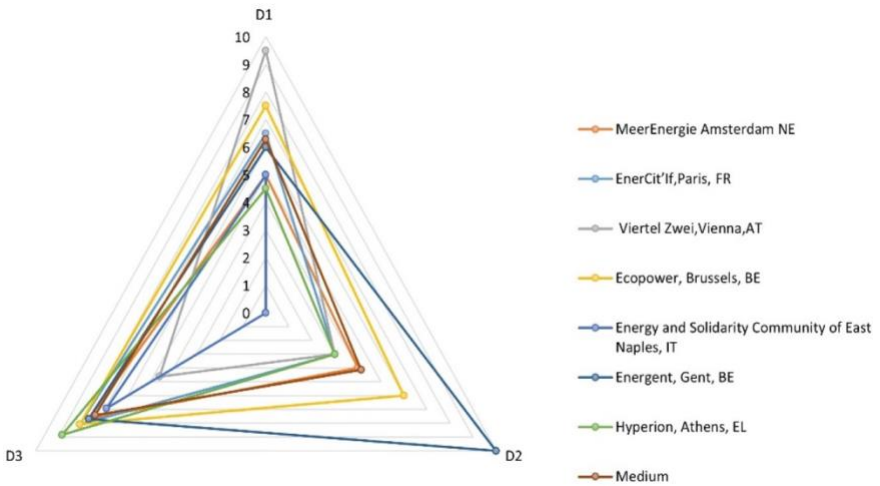
Indicator		Description
GENERAL	Location	DEGURBA classification of the territory. [9]
	Year of start	Year of creation of the legal entity
	Social Objectives	Objectives to be achieved in the social field
	Economic Objectives	Summarise the economic availability and issues input of the project
	Climate Objectives	Climate target to reach with the creation of the E.C
	Technical Objectives	Optimizing the technical solutions
	Position	The correspondence, or not, between the community and a specific area. [10]
	Spatial distribution	How the area, where is collocated the E.C., is spatially localized
	Limits	Boundaries of the expansion of the E.C
ENERGY	Activity	The main activities in which the E.C. is involved [11]
	Installed Elements	Number of elements installed in the implant
	Year of installation	Year of installation of the implant
	REs	Typology of renewable energy technology used
	Technical specifics of the Res	Specificity of the used renewable energy technology
	Production	Amount of kW of the plan
	Energy Provider	Energy society involved [12]
	Energy Storage	Usage of batteries to collect energy

*(continued)*

**Table 3. (continued)**

STAKEHOLDERS	Legal entity	Typology of entity instituted for the administration of the E.C. [13]
	Organization	Centralized: only a small and exclusive set of actors hold positions of power. Decentralized networks where power and control are over several actors. [14]
	Governance	Relationship between the internal parts of the legal entity
	Initiator	the institution / the person who starts the cooperative
	Type of members	The E.C. 's involved consumers, stakeholders, and prosumers
	Catchment area	Number of inhabitants involved in the E.C
	Accessibility	Ease entry into society
	Data visualization	Transparency in the diffusion of the E.C. data
	Affordability	Average amount of money needed to become a member and general benefits
SOCIAL	Inclusion	Stakeholders involved (focus on vulnerable groups) [8]
	Dissemination	How information, knowledge and participation are disseminated
	Social Impact	How much social impact is assessed during the establishment of the cooperative
PRODUCTION	Heritage	Inclusion of building that have a historical or cultural value and in which role
	Public Buildings	Inclusion of the public buildings in energy production and in which role
	Public Spaces	Inclusion of public spaces and in energy production and in which role
	Social housing	Inclusion of social housing in energy production and related spaces
	Private Buildings/spaces	Inclusion of Multi apartment buildings in energy production and in which role
	Main Problems	Description of the problems linked to the creation of the EC

**Fig. 1.** Radar indicating value of D1, D2, D3 driver for each case studio and reference to average values.



The energy community *Viertel Zwei*, located in *Vienna, Austria* scores the highest (9,5/10) in D1. The community has a strong technical component (Production, Distribution, Sales to third parties, Storage, Smart meters installed, Digital data access) which is used to enable the creation of a *P2P* (peer-to-peer) platform for local energy trading. Although the energy community is the most developed in the technical area, the performance of the other drivers is below average. In the case of *Energent*, D2 has the highest value (10/10). The result proves that the energy community provides a substantial decrease in the city's emissions (1390 tCo<sub>2</sub>, or 19% of the total). The use of wind technology allows a large electricity production (about 85GWh), which contextualised in *Belgium* (GHG emissions per kWh = 154gCo<sub>2</sub>e, characterised using natural gas, 31%, and oil and derivatives, 19% source: *Eurostat*) is significant for the energy transition. In this case, the D1 (6/10) and D3 (7.69/10) values are discrete but not far from the average values found (average D1 = 6.29/10, average D3 = 7.42/10). *Hyperion*, *Greece* obtains the best D3 value (8.85/10). This RES firstly aims at the alleviation of energy poverty, an important issue in *Greece* and especially in *Athens*. The inclusion of different stakeholders (physical persons, legal entities and vulnerable households) allows for greater outreach in the city's energy sector together with its distinguished special focus on vulnerable groups, making their inclusion possible through an increase in other stakeholder shares. Inclusion and governance considerations may influence the scores on the other factors such as D1 (4.5/10) and D2 (3/10). In the case of *Viertel Zwei*, the possibility of choice and participation falls on P2P energy trading. For *Energy and Solidarity Community of East Naples*, decision-making

power is restricted to entities (*Legambiente, Fondazione Famiglia di Maria, Fondazione Con il Sud, 3E-Italia Solare*) that manage the energy community, thus making D3 as the best performing driver.

### 3.2 Identification of the Measures for the Development of REC in Urban Areas

A total of twelve measures were identified, which are as follows (Table 4). A more detailed explanation of the reported measures and their relevance to an urban energy community follows:

**M1 Use of the Most Efficient Renewable Sources:** The measure involves a conscious study of the potential of the specific site to place the most efficient technology according to the most favoured renewable energy source. The measure aims to relieve the continued pressure on energy providers (state or private) and provide increasingly strong energy autonomy for community users.

**M2 Subsidies/Bonuses for Low Input Costs:** Entry into the energy community should not entail high costs to citizens. The measure could include use of social bonuses for physical construction of the system both externally (hence production) and internally (hence consumption) to individual households.

**M3 Direct Access to Self-generated Energy:** Measure aimed at raising energy awareness. Using self-produced energy would mean greater awareness and involvement in the energy community.

**Table 4.** List of measures and importance of them for an energy community, indication of the references used and the involved topic

Measures	Case studies
M1	Use of the most efficient renewable sources 0/7
M2	Subsidies/bonuses for low input costs 5/7
M3	Direct access to self-generated energy 7/7
M4	Awareness campaigns 7/7
M5	Subsidies or incentives for social inclusion 5/7
M6	Reuse of energy waste 1/7 (MeerEnergie)
M7	Energy storage 1/7 (Viertel Zwei)
M8	Maximization of production 0/7
M9	Smart meters 5/7
M10	P2P exchange 1/7 (Viertel Zwei)
M11	Founds for self-sustaining All
M12	Autonomous energy network 1/7 (Hyperion)

Legenda for determining the main reference scope of the measures.

Technical topic	Climate topic	Social topic	Climate+ Social	All topics
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**M4 Awareness Campaigns:** Providing social campaigns to raise awareness of conscious energy consumption. Provide tools for reading data, understanding voluntary energy waste to implement social change.

**M5 Subsidies or Incentives for Social Inclusion:** Foster the inclusion of the most vulnerable portion of the population through customized tariffs and methodologies. This would be a strong aid toward mitigating the energy poverty problem.

**M6 Reuse of Energy Waste:** To avoid energy waste and decrease GHG emissions into the atmosphere, encourage specific measures for the dual use of energy already produced for other purposes. Mainly focus on the reuse of heating.

**M7 Energy Storage:** Energy storage measure, aimed at ensuring the presence of a minimum amount of energy to soften situations of uncertainty (related to source non-constancy) or peak (related to the simultaneous use of numerous stakeholders).

**M8 Maximization of Production:** Specifically, this includes the design of a plant larger than the planned consumption of the stakeholders involved to sell/market/supply the surplus energy.

**M9 Smart Meters:** Installation of smart sensors to accurately understand usage, time slots and changing habits related to energy use (e.g. apps that allows real-time visualisation of consumption rate).

**M10 P2P Trading:** Creating platforms/agreement to provide stakeholders the opportunity to buy and sell their energy share among peers. It would provide increased sense of belonging to the energy community, possibility of earning or saving money, and awareness in consumption.

**M11 Funds for Self-sustaining:** Using the economic return of the energy community as the main source for the development.

**M12 Autonomous Energy Network:** Creation of a network connecting the stakeholders involved (thus possibly including an energy provider) that are completely autonomous from the common grid.

## 4 Conclusions

The aim of this work was to understand what is currently being developed in the urban sphere, trying to grasp its main characteristics to facilitate the design of REC in cities. Wind, sun and water are common goods, and therefore they can ensure fair access to the benefits of renewable energy generation to all citizens. Generally, we highlight that the social component plays a key role in urban areas. In fact, the average result of D3 amounts to

7.42/10, thus underlining the characteristic social footprint of energy communities and highlighting the importance of a strong social and governance framework, despite the climate and technological background, assumed in the definitions of the same provided by the European Commission. Indeed, in most cases these are cooperatives, where the main purpose is social, environmental, and economic, and all of them do not list profit as one of their main purposes. For this reason, the identification of potential measures touch upon all the three drivers, nevertheless integrating the social components in most of them. Future research would need to test the developed measures in real urban case studies, with the possibility of framing a multicriteria analysis to support decision over the most suitable measure to be implemented according to the main objectives of the communities considered.

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