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Spatial Planning for Energy-Resilient Territories and Cities

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Summary

This thesis focuses on spatial planning for energy-resilient territories and cities. It addresses the energy transition in line with the climate-neutral 2050 strategy by integrating energy systems development within urban areas. The goal is to help mitigate climate change and achieve decarbonization goals through community energy projects. Renewable Energy Communities meet the needs for energy security and accessibility to a clean energy economy, making urban areas more self-sufficient and resilient. The research constructs models and tools for analyzing energy systems at territorial scale using a place-based approach. It combines technical analysis of databases with constructing energy-spatial strategies to improve multilevel coordination between public authorities. The goal is to find the intersection between energy and spatial planning by implementing energy-driven spatial planning instruments and actively engaging citizens.

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Chapter 1

Introduction

1.1 Research topic

The strategic importance of incorporating the energy issue into the decision-making process is widely recognized, particularly by the 2016 Urban Agenda within the framework of the EU SDGs. The energy sector is the cause of two-thirds of global climate-changing gases, of which 80% are associated with urban activities. Addressing the energy transition is one of the priority issues in developing an **integrated energy system** within urban areas that must guarantee that cities effectively mitigate climate change and achieve their decarbonization goals.

The EU Clean Energy for All Europeans package supports this transition through measures to improve the energy system's security, sustainability, and competitiveness. This package includes adequate infrastructure and regulations to integrate renewable energies, satisfy market demand, and ensure energy supply security. These aspects are closely related to the importance of energy supply and demand spatial proximity. In this context, **Energy Communities** (ECs) offer a solution for energy security and access to clean energy. Therefore, it is an opportunity to improve the integration of energy and spatial planning to address current urban challenges.

This research aims to find the fertile **intersection between spatial planning** and **energy** to guide the energy transition of territories. The research focuses on developing energy-driven plans and platforms that utilize energy models and

engage citizens actively. This work is helpful to decision-makers who need to guide the perspectives of planning instruments in the energy field. It focuses on the importance of the spatial dimension within the plan, suggesting that the vast area is best suited to capture the different aspects of the energy variable when considered in urban instrumentation. The policy implications imply a restyling of the architecture and methodological approach of ordinary planning to foster better integration between energy and spatial planning.

1.2 Motivation

The first reason I chose this research topic is related to my **background** and **experiences**. I have a bachelor's degree and a master's degree in territorial, urban, environmental, and landscape planning. My research in the energy field began with an internship at LINKS Foundation, where I studied contractual models for energy communities. I continued this work with my thesis, "Energy Communities and Spatial Planning: The Piedmont Region Case Study," which developed a methodology for sizing energy communities based on the Piedmont Region's first law on energy communities. Then, I have dealt with energy issues related to planning since 2019 with an internship at the International Energy Agency (IEA) in Paris. Later, with the topic of energy communities in my master's thesis and a research project, coming to collaborate on the energy cluster of the R3C research center.

The second reason that led me to address this issue is the **energy sector's strategic importance** in mitigating climate change and achieving decarbonization goals. Energy production and consumption causes two-thirds of global emissions of climate-changing gases (IEA, 2015). Furthermore, about 80% of energy consumption and CO2 emissions in Europe are associated with activities in urban areas (EEA, 2013). The energy sector holds the solutions to the world's climate change since it is the primary source of global emissions (IEA, 2021). It is widely recognized the role of energy efficiency policies (Tanaka, 2011) and renewable energy for reducing climate change emissions and promoting sustainable development (Sims, 2003).

In literature is recognized the direct and reciprocal relationship between the dimensions of energy and spatial planning (Owens, 1986). Moreover, several authors consider spatial planning as a means of addressing the challenges of climate change and energy transition (IPCC, 2021; Agenda, 2030).The work focuses on the **Italian context**, where energy topics and spatial planning are treated sectorally

without communicating (De Pascali & Bagaini, 2021; Zanon & Verones, 2013). In the Italian case, the primary energy issues are dependence on foreign purchases and low coverage from RES. Dependence on foreign purchases and extensive use of natural gas is one of Italy's main problems; a small part of the consumption derives from internal production, and there is a strong dependence both on foreign countries and on natural gas (Eurostat, 2020). These factors make Italy dependent on foreign states and consequently more subject to price variations and, therefore, less resilient to unexpected events.

It is essential to focus on **renewable energy sources** to reduce dependence and the environmental impact of energy. Italy aims to reach 30% of the gross final energy consumption from renewable sources (PNIEC, 2019). Renewable sources are practically inexhaustible, but their possibility of use is limited because of the dispersed nature of energy sources, the limited availability in time and discontinuity of generation, and their accessibility related to constraints of a different nature.

Due to these characteristics, this trend, which foresees RES growing in the following years, must be planned. This trend must be planned in the territories using Energy Communities. This new union of users is fundamental to promoting energy sustainability and bringing energy consumption together with energy production (Mutani et al., 2021). ECs are an **opportunity** to **increase** the **integration** between energy and spatial planning, still treated sectorally, to face the current urban challenges (Brunetta et al., 2021; ASUR, 2021).

1.3 Research gaps

Following the analysis of the literature, the issues raised by some articles were identified in the following points divided in policy and technical issues. The analysis is better addressed in Chapter 4.4. From the policy side literature highlighted:

- **Lack** of **integration** of energy strategies into spatial planning (Balducci, 1991; Mazza, 2004, Zanon & Verones, 2013)
- General **absence** of a **strategic dimension** in urban planning in favor of sectorial actions with a short-term vision (Brunetta et al., 2020).

From the technical side literature highlighted:

- **Lack** of **spatial dimension** of energy data (Stoeglehner et al., 2016)

- **Low technical knowledge** and **expertise** with regulation constraints of the local authorities (Lombardi et al., 2010).

The work addresses solutions for overcoming energy planning barriers in the Italian context, analyzing new methods and procedures of spatial planning.

1.4 Research goals

The research goals are divided into technical and political and are closely related to each other. It combines technical analysis of energy-related data with developing spatial-energy strategies to improve coordination among public authorities. The analysis implemented will be tested in the Metropolitan City of Turin.

The technical goals are working on **models** and **tools** with a place-based approach. The aim is to find the optimal dimension and spatial distribution of ECs and identifying the most effective spatial energy policy.

From the policy side, the object is planning **spatial-energy strategies** to enhance multilevel coordination among public authorities. The aim is define different policies to encourage the creation of energy communities and integrate the ECs into spatial planning as a driver of the energy transition.

In conclusion, this work aims to discuss the lack of integration between spatial planning and energy in Italian planning systems and take a step forward in the research debate by developing energy-driven plans, energy models, and encouraging citizens' involvement.

1.5 Research questions

Considering the main objective of this research, the focus of this study rotates around specific topics that were selected and addressed according to the set objectives. Due to time constraints, it was necessary to define the boundaries of the research topics. Specifically, the decisions followed were to address the next research questions and topics:

How can energy strategies be integrated into territorial planning? The research addresses several questions related to integrating energy strategies into territorial planning. The approach adopted is the **mainstreaming adaptation** for energy resilience by introducing measures for transition, adaptation, efficiency, and green conversion of networks into territorial and urban planning tools by

developing energy-driven plans. Moreover, Energy Communities are a crucial opportunity to guide and accelerate the energy transition with communities, making their planning and management crucial for energy and spatial planning.

How can energy be approached in spatial planning? In order to improve the level of integration between planning and energy, an in-depth literature review on energy planning in Italy guides the choice of scale and planning tool to be adopted. The choice was to apply a **restyling** in the architecture and methodological approach of ordinary planning instruments at the vast area scale. The work, proposes an energy-oriented meta-plan using the Territorial Energy Basins (introduced in Law 10/1991) as a structural guiding element to implement specific strategies based on the characteristics of the territories.

What are the best practices in spatial planning for energy transition in cities? The research analyze **best practices** in spatial planning for energy transition to identify successful models, highlight strengths and weaknesses in integrating energy into spatial planning processes. The cases analyzed are two Emilian energy plans, a region at the pioneering stage, and the Danish case for community energy projects application.

Considering the specific territorial characteristics, how can we sustainably drive the energy transition? **Place-based tools** and **models** provide information at different scales to support policy and decision-making in order to achieve a sustainable energy transition considering the territorial characteristics. The goal is to develop specific tools to incentivize the development and management of energy communities and measure their energy, environmental, economic, and social impact on a territorial scale.

How do we measure the energy resilience of territories? Another objective is to define indicators for **measuring** the **energy resilience** of territories in spatial plans and projects to support planning decisions. Measuring the energy resilience of territories is a subject that still needs to be explored scientifically. One of the objectives of this research work is to define a set of indicators applicable to spatial plans and projects that allow quantitative and qualitative measurements.

1.6 Organization of dissertation work

The research work is composed of four main sections. The first part provides a theoretical framework of the issues addressed, and the second is a practical analysis

to establish a scientific basis for the research. The third analyzes best practices in the field. The fourth and final section focuses on the conclusion for the next generation energy plan with an application and experimentation of the research proposal.

The first section, which provides a theoretical framework, in chapter one, highlights the strategic importance of sustainability in the energy sector and analyzes the energy situation at different levels. Chapter two investigates the relationship between energy and the urban system, focusing on the interactions between land and energy. Chapter three examines the energy planning tools in Italy and their characteristics. Chapter four introduces the concept of energy communities, their history, regulation, and benefits to communities.

The second section focuses on a practical application, in particular in Chapter Five, implementing a methodology for assessing the pre-feasibility of a Renewable Energy Community. In Chapter Six, a territorial and energy analysis at a vast scale (the Metropolitan City of Turin) was implemented.

The paper's third section analyzes best practices, examining the Emilia-Romagna region applications, with two energy plan cases (Bologna and Modena) and one Danish concerning community energy applications.

Finally, the fourth and last section of the paper addresses the application and experimental proposal, which involves the adoption of a "meta-plan" with energy value based on the case studies analyzed in the practical section. In particular, using Territorial Energy Basins (BETs) as an aggregation method that joins energy and planning tools. In conclusion, the work summarizes the considerations and solutions to overcome the barriers to energy planning in Italy.

Chapter 2 Theoretical framework

The energy question

2.1 Energy, environmental issues, and sustainability

The strategic importance of the energy sector

From an energy point of view, three macro-trends will characterize the future: the increase in population in cities, the scarcity of natural resources, and climate change. The increase in population in cities will lead to an increase in the density of energy demand in punctual locations, the scarcity of natural resources will force us to depend less on them, and climate change will lead to the need for resilient energy infrastructures and sustainable energy use. These trends will necessarily bring to the definition of a **new energy model** that will present crucial challenges regarding reliability, accessibility, and energy sustainability. The transition to a new energy model is a challenge that can represent an opportunity for the sustainable development of the territories.

For these reasons, this research topic is of central importance in the scientific field since the energy sector is the primary source of global emissions and, therefore, holds the solutions to respond to the world's climate change. The energy sector **strongly influences climate change**. Specifically, energy production and consumption causes two-thirds of global emissions of climate-changing gases (IEA, 2015). Furthermore, about 80% of energy consumption and CO2 emissions in Europe are associated with activities in urban areas (EEA, 2013).

To achieve the decarbonization goals and mitigate climate change, addressing the energy transition by integrating the development of energy systems within urban areas is central. Spatial planning assumes fundamental importance in guiding the ecological transition process on the territories from an energy point of view.

Italy must follow this path to fully implement a balanced energy transition, with the ambitious goal of completely freeing from fossil fuels and continuing to be a

key player in the fight against climate change. Adopting a transversal approach, with a coherent vision of all the different aspects of energy, to accelerate greenhouse gas emissions reduction, in line with the long-term goal of deep decarbonization by 2050. The gradual elimination of fossil fuels in energy production and consumption, the diffusion of renewable energies, the minimization of environmental impacts, and energy efficiency are the fundamental steps to contribute to environmental protection objectives and reduce dependence on fuels and foreign fossils while supporting economic growth.

Globally, according to Our World in Data, 2020 (Figure 1), the primary source of greenhouse gas emissions is energy production, which accounts for **73%** of **all emissions**. This figure highlights, even more, the extent to which the problem relates to energy use and management. Therefore, the actions to fight climate change are mainly related to energy, delineated in many areas and aspects. Given the sector's increasing relevance in the coming years, more funds will progressively go to the energy transition.

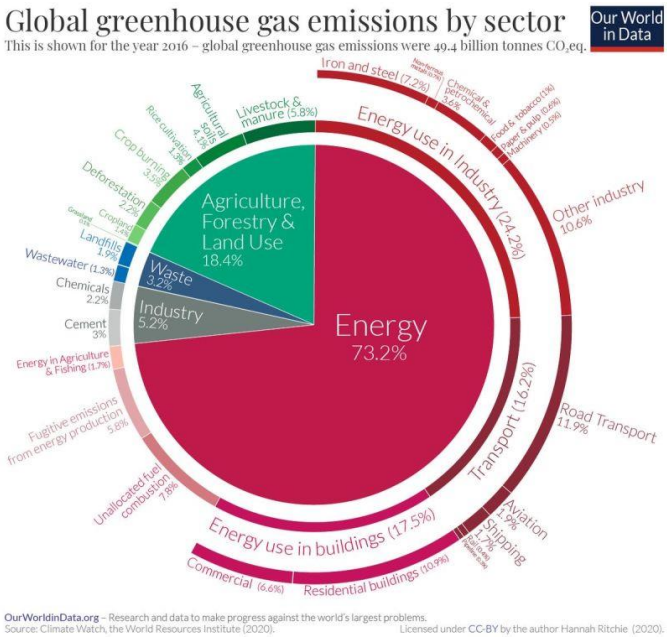


Figure 1: Global greenhouse gas emissions by sector (Our World in Data).

Energy in the modern world: the fossil fuel civilization

The challenge to climate change is currently the most critical. In this context, the management of urban areas, becomes increasingly important, and consequently, spatial planning is the key to addressing these problems. The urbanized areas,

densely populated, represent the most energy-intensive places in the territories. In particular, the primary urban energy consumption concerns the comfort of homes, namely the lighting, the heating, and the cooling of internal environments. In the contemporary world, the most advanced countries achieved benefits that emerging countries will achieve in the future.

In this context, **energy spatial planning** is potentially a territorial governance tool suitable for coordinating various environmental, settlement, climatic, and socio-economic development aspects. Fixing guidelines, objectives, and regulations specific to each territory and situation is a fundamental tool for the energy transition. The policies relating to the energy sector are fundamental to achieving a gradual transition toward the low-carbon economy with less impact on the environment. These policies present a multisectoral and multi-scalar dimension, allowing consideration of all aspects of the territory's characteristics.

The relationship between spatial planning and energy has been emphasized in Chapter 3 and is evident in urbanized areas. The relationship between the parties is bidirectional, territorial choices impact energy consumption and production. On the contrary, energy production and consumption influence spatial decisions. With its tools, territorial planning can combine urban transformations with sustainable development, intervening with targeted policies with a holistic approach.

Modern civilization has been established based on the use of **fossil fuels**. These fuels have provided affordable energy, empowering economic growth and technological progress. However, their excessive use has resulted in damaging environmental impacts, such as air pollution, increased greenhouse gas emissions, and climate change (Smil, 2017). Moreover, it is essential to consider that energy consumption has been rising steadily since 1970, with some reductions in the years corresponding to major economic crises or international events (Figure 2). Despite this, the consumption trend continues to rise, a phenomenon caused mainly by developing countries, China among them, which do not want to be subject to restrictions on reducing climate-altering gases as they are now in their development phase.

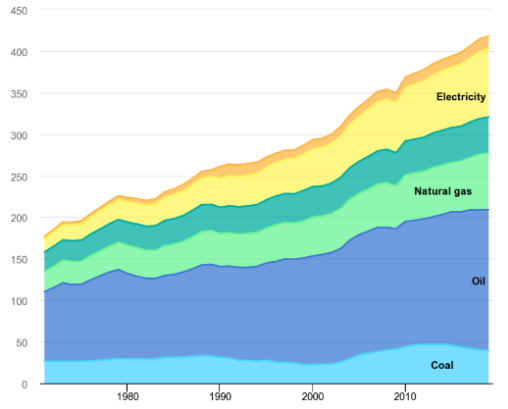


Figure 2: Consumption trends over time (IEA, 2022).

Climate change must be faced adequately with mitigation and adaptation policies seeking as much as possible to adopt integrated approaches and measures to reduce the impacts and vulnerabilities of rising temperatures.

Energy in the future

The Intergovernmental Panel on Climate Change (IPCC, 2021) confirms that the global temperature has warmed by 1.1 degrees Celsius compared to the pre-industrial era. They also highlight how stabilizing the temperature requires net zero CO2 emissions and substantially reducing other greenhouse gas (GHG) emissions. In order to prevent global temperatures from rising above **1.5°C**, we need to limit our current rate of emissions. This means we have only few years to act. The report also emphasizes the rise in extreme weather events, such as heat waves, floods, droughts, and storms.

The first choice as an energy carrier is **electricity**, the cheapest, most flexible, and most valuable form of energy. As we will see, energy and the environment are directly related. The extraction, transport, processing, and combustion of fossil fuels and the production and transmission of electricity create a wide range of environmental impacts. Therefore, renewable energy sources sustainably generate electricity. Geothermal energy production is a minor contributor; hydroelectricity is heavily exploited, biomass presents air pollution issues, and photovoltaic and wind power is expanding. Between 2000 and 2015, the former increased by about 230 times and the latter by about 27 times (Smil, 2017).

The multidisciplinary challenge of ecological transition

Nowadays, the concept 'energy transition' is used in the public debate, addressing(International Conference 16th AIGE in Parma, Italy, June 8-9, 2022, President of ENEA, Gilberto Dialuce):

- Transition: i.e., the time between the current situation and the future. Transition also implies that the contemporary world is inside and part of it.
- Energy: The energy sector alone does not encompass everything. Facing this topic in a sectoral way limits and precludes the challenge; therefore, it is better to speak of an 'ecological' transition, which in turn implies the energy transition.

The energy dynamics, as we have seen so far and as will be explored later, are highly complex and relate to spatial planning. Ecological transition is a multidisciplinary challenge (pollution, climate, environment, economy) at different scales (multiscale). These themes are traditionally and wrongly treated in a sectoral manner.

International discussion

States have only begun to discuss energy issues at the international level in recent decades. In 1992, **the Kyoto Protocol** and Agenda 21. In 2012, the document '*The Future We Want*' was adopted, a process to develop a set of sustainable development goals based on the SDGs. In 2015, with the **2030 Agenda** for Sustainable Development, with 17 SDGs at its core. In 2016, the United Nations New Urban Habitat III Agenda: Sustainable Cities for All. Today, the United Nations Department of Economic and Social Affairs (UNDESA) offers essential support and promotion on issues related to the SDGs. The seventh of the 17 Sustainable Development Goals is related to energy dynamics. While goal number 11 is the sustainable development of cities and communities, we must change the scale of the problem, no longer the building scale. However, it is supposed to be the community, the city, and the territory scale.

Trilemma Index

The concept of energy sustainability dictated by the Energy Trilemma Index evaluates the energy sector internationally. The energy trilemma is vital for assessing a country's energy condition. In particular, the principles of the energy trilemma guide the choice of energy sustainability of territories about three components:

1. **Energy security**: Effective energy supply management with reliable infrastructure to meet current and future energy demands.
2. **Environmental sustainability**: Involves achieving supply and demand-side energy efficiencies and developing energy supplies from renewable and low-carbon sources.
3. **Energy equity**: Includes the accessibility and affordability of energy, including the right of people to access energy from a physical and economic point of view.

Energy resilience in scientific debate

The scientific community has been discussing the concept of energy resilience for a few years. Despite this, it has undergone an evolution and new considerations. Fonseca et al., 2017 consider **diversity** as a critical feature in improving energy resilience. At the same time, Ribeiro D. et al., 2015 interpret the pattern of **energy efficiency** as an opportunity to think resiliently. Barrocca (2019), examines resilience and **self-sufficiency** as synergic concepts. In Gatto and Drago (2020), the authors conducted a literature review based on 41 publications to clarify the concept of energy resilience. To this end, they proposed a **taxonomy**. The results indicate a conceptual evolution, moving beyond the initial approach that limited the use of resilience to the complex and technical sciences. Resilience is now viewed holistically and applied across multiple disciplines, including social sciences and sustainability studies, focusing on sustainable development. Then, the authors (Gatto & Drago, 2020; Koutra et al., 2022), to interconnect the terms of energy and resilience, show the emerging concept of **urban resilience**, highlighting how there is no standardized definition for the resilience of an energy system and that it varies depending on the context, risks, and goals.

Therefore, the energy dimension of the territorial system aims to be the main component of the planning project to improve the system's resilience (Sharifi & Yamagata, 2015). According to Sharifi & Yamagata, 2016, for urban energy systems to be resilient, "*they need to develop the ability to prepare* ***to absorb, adapt to, and respond*** *to unexpected changes*". Integrating these abilities within the **territorial energy systems** should improve the four dimensions of sustainability of an energy system, which concern "***availability, accessibility, responsibility,*** *and* ***acceptability***" (Brunetta et al., 2019). Energy resilience is a dynamic process that is constantly changing. Future insights of this argument are how to measure territorial energy resilience, the theme that comprehends the

evaluation of the energy vulnerability, and the implementation of a multi-criteria approach to spatial analysis.

Energy planning for territorial resilience in strategy and policy

Measure energy resilience for the design of planning processes, is a subject that still needs to be explored scientifically (Bahadur & Tanner, 2014; Davoudi et al., 2013; Folke, 2006). With the National Recovery and Resilience Plan (PNRR, 2021), Italy has launched a strategic plan for the modernization of the country through six areas of intervention, supported by a significant amount of funds. The Plan is built on three strategic axes shared at the European level: digitization and innovation, ecological transition, and social inclusion. The ecological transition component pursues the strategic objectives of decarbonization through five lines of reforms and investments. The first line, which aims to increase renewable energy (with 5.9 billion euros and 2.2 billion for the energy community), is essential for this work.

Italy aims to satisfy 30% of final consumption by 2030 (PNIEC). In this perspective, declining the resilience concept inside the spatial energy planning process can support territories' energy transition toward achieving sustainable development (Sharifi & Yamagata, 2016; Brunetta et al., 2019). Orienting energy planning to resilience is necessary to direct the development processes towards sustainability targets, shared internationally with the adoption of the SDGs (UN, 2015).

The concept of resilience imply the capacities of self-organization, adaptation, transformation, and innovation of a territorial system. Two specific dimensions of a resilience-oriented spatial planning approach are highlighted (Davoudi et al., 2012; Meerow & Newell, 2019; Vale, 2014). Primary, the ability to focus action on the **dynamic co-evolution** of the system, and second, the ability to promote a **holistic** vision and **multi-scalar** governance oriented to the definition of adaptation strategies and actions (Brunetta & Caldarice, 2020). Therefore, the energy dimension of the territorial system is the main component of the planning project aimed at improving the system's resilience (Brunetta et al., 2021).

In this perspective, territorial resilience does not result from a conventional top down process. However, it is instead a **place-based** and **proactive** vision of territorial systems for implementing collective and individual actions, managing unforeseen events, and improving environmental and social quality (Brunetta et al.,

2019). "*Social and institutional learning capacity is the essential factor in driving territorial resilience*" (Brunetta & Caldarice, 2020). Indeed, by initiating direct and mutual relationships, local communities and institutions initiate a process of reciprocal learning and innovation.

The goal to aim for is the **mainstreaming adaptation** approach for energy resilience. This goal involves introducing measures and actions to transition, adapt, increase efficiency, convert networks into green ones, and integrate the concept into the regular instruments of territorial and urban planning (EU, 2021). Energy planning could better meet the needs of governing districts and homogeneous morphological and settlement areas, suggesting new strategies for the ecological transition of the territories. In this essay, the multidimensional and multiscalar scope of territorial planning for energy resilience emerges, enhancing the characteristics of the local morphology of settlement to implement sustainable models of development of natural and anthropic resources of the territories.

2.2 Energy in sustainable development

Fossil and Renewable Energy Sources Introduction

We have seen how modern civilization was built using fossil fuels such as coal, oil, and natural gas, which allowed the realization of the developed countries. However, excessive use of fossil fuels has negative environmental consequences, such as air pollution, increased greenhouse gas emissions, and climate change, making this growth pattern unsustainable for life on Earth. It is essential to focus on renewable energy sources to reduce energy dependence on foreign states and the environmental impact of energy. With the PNIEC (Energy and Climate Plan), Italy aims to reach 30% of the gross final energy consumption from renewable sources. Renewable sources are practically inexhaustible but their **possibility** of **use** is **limited**:

I. Because of the **dispersed** nature of energy sources with considerable dimensions and significant use of the territory, it is shifting from a centralized model to a decentralized one. The paradigm shift implies energy production made by small plants spread throughout the territory, particularly in those with more natural resources, in contrast to energy production concentrated in a few large plants that today meet energy needs.
II. Because of the **limited** availability in time, the biggest problem of depending on these sources is their discontinuity of generation related to weather

conditions that change from season to season and during the day. This limitation implies energy management problems, considering that the electricity produced should be consumed immediately, or using storage systems (today, it still needs to be more impactful on the environment and too expensive). An optimal solution is to evaluate a proper energy mix in space and time.

III. Is **accessibility** related to the presence of **constraints** of a different nature. The accessibility of renewable resources in Italy, in particular, is strongly constrained by regulations aimed at safeguarding landscapes, assets with historical value, and limits for environmental protection, which are set by the regions that follow state-level guidelines.

Given ambitious targets and dedicated funds related to renewable energy sources, the goal is to **plan** the increase in RES in the **territories** considering their limitations.

Achieving net zero emissions by 2050

In the European Union, 75% of greenhouse gas emissions derive from energy production and consumption. Decarbonizing the energy system is crucial in meeting climate goals for 2030 and long-term neutrality goals by 2050. Specifically, to meet the **2030** climate goals, it has committed to transforming EU climate, energy, transport, and taxation policies to reduce greenhouse gas emissions by at least **55%** from 1990 levels. Through the European Green Deal, the EU, to achieve its **long-term goals**, focuses on three core principles to reduce greenhouse gas emissions and improve quality of life:

1. Ensure a secure and affordable energy supply (energy security).
2. Implement an integrated, digitized energy market (smart cities and communities).
3. Focus first on energy efficiency, then to develop an energy sector based mainly on renewable energy sources (energy efficiency and RES).

Scientific research helps identify pathways to achieve zero emissions. Among them is the Net Zero Emissions (NZE) by 2050 scenario from the International Energy Agency (IEA, 2022), one of the most important international agencies in this field. The NZE scenario highlights the need for an essential energy production and consumption transition. Implying electrification of end uses, more efficient

energy technologies, and behavioral changes. These improvements will decrease energy demand but, at the same time, increase GDP.

By 2030, about half of the energy supply is expected to come from renewable energy sources. The share of renewable energy in global electricity production reached 28.7% in 2021 (Figure 3). Renewable energy production must grow by at least **12% annually** between 2022 and 2030 (IEA, 2022) to reach the Net Zero Scenario (61%) goal. The acceleration of wind and solar capacity addition drives renewable energy growth, but action must be accelerated quickly to meet a zero emissions scenario (Smil, 2017; IPCC, 2022).

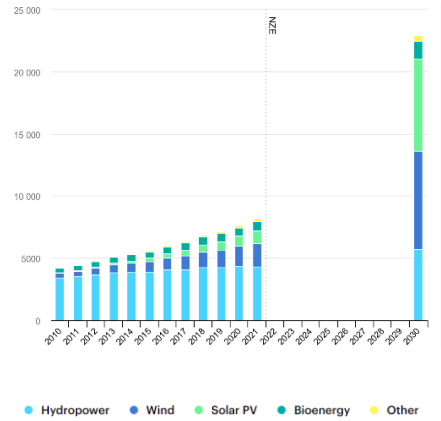


Figure 3: NZE scenario (IEA, 2022).

The diffusion of low-emission technologies will require an increase in investment in the energy sector, which should increase by about **twice** if compared to recent years. With all the uncertainties involved, this scenario analysis attempts to broadly define the main directions the energy sector will have to take soon. The focal points are massive electrification of end-use consumption and increased government funds to invest in energy efficiency and low-emission sources.

Building Resilient Infrastructure objective

The transition to clean energy puts the electricity sector and electricity security at the center of discussion about the future of the power sector. The main challenge will be to **match electricity supply** and **demand** by increasing the share of multiple energy sources, such as wind and solar PV. Related to this, there are many other challenges. The impacts of climate change and cybersecurity threats pose risks to electricity security in which electricity will cover a large share of demand. Ensuring

electricity security requires identifying, managing, mitigating the most vulnerable areas and preparing for breakdowns (IEA, 2020; Brunetta et al., 2021).

Energy community's

The resilient infrastructures debate includes Energy Communities (EC), which are new organizational entities that boost local energy sources while considering local demand. The energy users decide to make common choices to meet their energy needs and maximize the benefits of their standard approach. Distributed generation solutions and intelligent management of energy flows allow these communities to achieve collegiality. The energy sources should be local and renewable. Users can exchange excess energy production from renewable sources, bringing economic and environmental benefits, thanks to a series of incentives and energy produced locally. Energy Communities ensure that:

1. The consumption of energy is in concomitance with the production. Simplifying, the electricity we consume should be produced "instantaneously" Therefore, it is necessary to make the two coincide.
2. The network infrastructures can manage energy fed into the distribution networks. This dynamic sets a new spatial dimension for energy related to the distribution system.
3. The new plants constitute an economic opportunity for the territories concerned. This situation can benefit rural areas, mainly where RES are more suitable for installation, and territories present dynamics of depopulation.

ECs incentivize the energy consumed locally and simultaneously and the energy production from RES. In addition, they ensure that the revenues are not destined for financial profits but for improving the energy independence of the territories. The following chapters will address this topic, central to this research.

2.2.1 Electricity

Electricity is a secondary energy source, so it derives by transformation from a primary energy source. It is easily convertible with high efficiency into mechanical, light, thermal, and other types of energy. It is usually measurable in kilowatt-hours (kWh), equivalent to 3.6 MJ. The advantages of this energy source are that its transport can be over long distances, the operating noise is low, and exhaust fumes

are absent. The main disadvantage is that it needs a conversion infrastructure since it is a secondary source, which introduces a loss of efficiency.

It is necessary to make an in-depth paragraph on electricity to motivate the choices made in the research work. Electricity is now the most **flexible** energy carrier because it is producible in large quantities without relying on fossil fuels, can be generated locally in small quantities without batteries, and can be stored when not needed and used when needed. The increased flexibility of this type of energy carrier, along with solar and wind power plants, is due to advances in technological solutions in this field. However, the fact that the primary raw material for electricity generation is fossil fuels (mainly coal and oil) means that the environmental impact in terms of CO2 emissions into the atmosphere is very high.

Electrification

Climate change is forcing us to rethink how we use energy. The electrification of end uses is an essential tool to achieve the ecological transition and shape a sustainable development model (IEA, 2020; EU, 2021; Enel). Electrification of end-use energy use is the path to decarbonizing the economy, making transportation more efficient, and ensuring cleaner air quality. Technological advances make electricity more affordable than using fossil fuels in most cases. Today and increasingly soon, electrification options are cost-effective and accessible to most end-use sectors. For example, electric heat pumps offer the most incredible opportunity in buildings to replace fossil fuel boilers for heating (IEA, 2020).

How the national electric grid works

Electricity is relatively easy to find in nature but not so easy to 'capture' and use daily. Electricity must be transformed and obtained from other renewable energy sources using electrical machines and converters. The electricity grid is divided between consumers on the one hand and generators, power plants, and production facilities on the other. At the center is the electricity grid, consisting of high and extra-high voltage lines, which reach consumers through a distribution network that feeds electrical appliances (Figure 4).

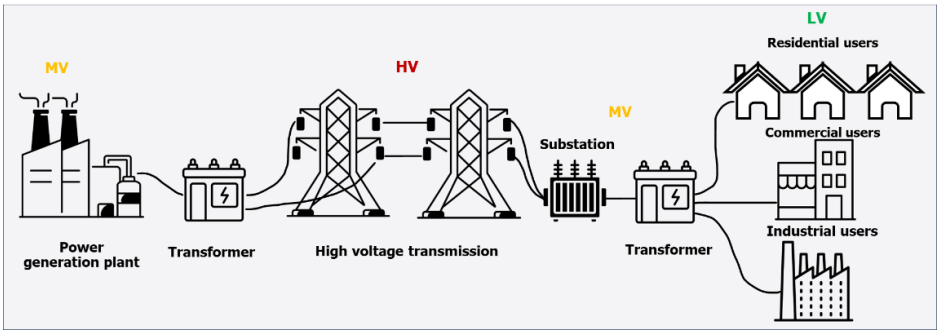


Figure 4: Diagram of the electricity grid.

The dispatch of electricity

The electricity grid is comparable to a balance: one side on which we put the energy demand, and the other is the energy that the power plants must produce and supply to the grid. This balance must be perfect so we do not produce more energy than we need and vice versa. Dispatching is a significant and complex activity to **manage energy flows**.

Distribution thus consists of coordinating the production and consumption of electricity from power plants through the grid, facilitating the full integration of the ever-increasing number of renewable energy sources. In Italy, Terna, which manages the high-voltage transmission grid, is responsible for this activity.

2.3 The energy issue in spatial planning

The strategic importance of incorporating the energy issue into the decision-making process is widely recognized, particularly by the 2016 Urban Agenda within the framework of the EU SDGs. Specifically, integrating energy into spatial planning helps reach Sustainable Development Goal 7 (lean and affordable energy). Addressing the energy transition is one of the priority issues in developing an integrated energy system within urban areas that must guarantee that cities effectively mitigate climate change and achieve their decarbonization goals.

The following sections analyze the current energy system from **European** to **Italian** until **Piedmont region** scale to understand better the starting situation, highlighting the main legislation and energy variables, and the trends that are on going. Renewable Energy Sources and their relationship to land and spatial planning are finally analyzed as the focus of the research work.

2.3.1 Overview of the current European and Italian energy system

European and national energy actors

At the supranational level, we find the European Union (EU): the European Parliament, the Council of the European Union, and the European Commission (EC). The EC represents the executive power of the EU. However, it also has essential legislative functions and must ensure the implementation of European directives, the harmonization of the single market, and various EU policies. The Directorate General for Energy and Transport (DG-TREN) is responsible for the energy sector. DG Environment fulfills this mandate by developing legislative proposals, managing programs, and financing projects.

At the **national level**, the legislative body is the Parliament. However, since energy is not an exclusive state competence under Article 117(2) of the Constitution (which defines the matters over which only the state has legislative competence), the legislative provision of the energy sector under paragraph 4 of that article is the responsibility of the regions. However, the part of the subject "*national energy production, transportation, and distribution*" is included among the subjects of 'concurrent' legislation under Article 117(3), so there is national and regional competence in this part. The regions have legislative powers, except for the determination of fundamental principles reserved for the state.

The government has essential functions of legislative initiative, as well as those of government action; the ministries involved are the **Ministry** of **Economic Development (MSE)**, structured in general directorates, of which the **Directorate General** for **Energy** and **Mineral Resources (DGERM)** is primarily responsible; competencies in this area are also of the MATT (Ministry of the Environment and Protection of Land and Sea), in particular with the "Division IX 'Renewable Energy' III Environmental Interventions, Energy Efficiency and Alternative Energy" for environmental protection it exercises the functions of competence in energy matters. The MEF (Ministry of Economy and Finance) also has functions indirectly related to tax incentives and concessions or fuel taxation. Finally, the last body operating on the subject is the CIPE (Interministerial Economic Planning Committee), whose deliberations concern the economic aspects of the sector.

At a lower level are the **Regions** with precise competencies in energy matters we have indicated (in addition to the territorial level with land-use regulations LR 1/2005 and the PIT-Territorial Address Plan). They differ from the **Provinces**,

which do not have legislative competencies on the subject but have essential "*operational*" functions, such as authorization functions (delegated by the Region) for Renewable Energy Sources plants and drafting of PEPs (Provincial Energy Plans), having energy policy functions, and PTCPs (Territorial Coordination Plans), having actual land-use government functions, in which implement energy aspects.

Municipalities can draw up PECs (Municipal Energy Plans) - the obligation applies only to municipalities above 50,000 inhabitants. They must implement the provisions stipulated in the PEC in their Municipal Structural Plans (Town Planning Regulations, Implementation Rules, and Building Regulations).

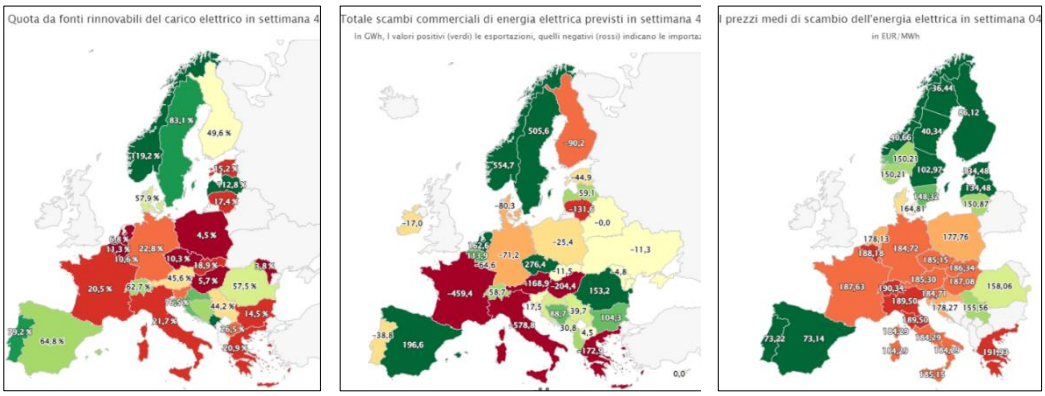
In addition, there are other institutional entities. The AEEG (Electricity and Gas Authority) is an independent authority established in 1995 that regulates and controls the electricity and gas sectors. The GSE (Gestore dei Servizi Elettrici), a joint-stock company established by Legislative Decree 79,199, manages incentives at the national level related to RES (Green Certificates, Energy Accounts). Terna - National Electricity Grid is a joint stock company that physically manages the National Electricity Transmission Grid. The Electricity Market Operator is the joint stock company entrusted with the organization and economic management of the electricity market to promote consistency among producers. With the operational start of the GME (2004), the electricity market in Italy was born, like in other European countries. The ENEA (National Energy Agency for New Technologies, Energy and Sustainable Economic Development) monitors energy savings resulting from energy services and other energy efficiency improvement measures introduced at the community level, including those at the national level. The agency has been redefined by Law 99/2009 and has research tasks in the energy field. It also develops technologies and knowledge while supporting public bodies.

European and Italian energy consumption and production framework

The European Union (EU) relies on energy imports from third countries to fulfill its energy consumption needs. As of 2020, the most significant imported energy product was oil, which includes crude oil, accounting for almost 66% of energy imports into the EU. Natural gas accounted for 27%, and solid fossil fuels accounted for 5% of the total energy imports. Russia is the largest importer of crude oil, natural gas, and solid fossil fuels (the state on which we are most dependent), followed by Norway for crude oil and natural gas (Eurostat, 2020).

The **dependency rate** in the EU (2020) was **58%**, met half of the EU's energy needs. This rate is lower than in 2019 (60%), partly related to the COVID-19 economic crisis, but still slightly higher than in 2000 (56%) (Eurostat, 2020). In this context, Italy present a critical conditions. It covers about 22% of RES's share of the electricity load and is the state with the **highest energy import** (Figures 5). This situation made the Italian state dependent on international events and, therefore, most subject to price variation.

Dependence on foreign purchases and extensive use of natural gas are the main problems for Italy; a small part of the consumption derives from internal production, and there is a strong dependence on foreign countries and natural gas. Italy **depends** for more than **75%** on foreign purchases.



(a) (b) (c)

Figure 5: European and Italian energy context maps to week 4 of 2023 (Energy-Charts).

For example, in 2022 Italy's dependence on foreign countries such as Russia. The 43% of the natural gas imported to Italy in 2020 came from Russia; due to the war between Russia and Ukraine, energy prices have risen (doubling or tripling the price compared to 2019), affecting the energy accessibility of the population. In addition, a study by The European House (Ambrosetti), ranks Italy fifth to last in Europe regarding energy autonomy, at around 22% of total consumption (compared to 40% in the EU). However, by exploiting its natural resources, Italy could increase its energy autonomy to **58.4%**. According to the study, Italy ranks second in Europe for the **availability** of **renewable resources**. If they were exploited effectively, along with measures such as electrification of consumption and improvement of energy efficiency, energy autonomy could triple from current levels and increase

by about four times. However, despite using all available renewable resources, meeting our current energy consumption would not be possible.

Hydro has been the most consumed source , remaining constant over the last five years, making almost total use of waterways. This is followed by solar, wind and bioenergy, which show significant growth over the past 15 years. Finally, a smaller share of geothermal energy is visible, which has been constant over the past 15 years (Figure 6). It is also noticeable how, in the last 15 years, total production from RES has doubled (from 4.8 Mtoe to 10.2 Mtoe), and consumption has decreased slightly (particularly in the 2020 effect caused by COVID-19). Finally, Figure 7 looks at the share of fuels in total energy consumption. The Figure shows, values in line with the EU average, highlighting higher consumption of the natural gas by the Italian state(29% Italy versus 20% European average).

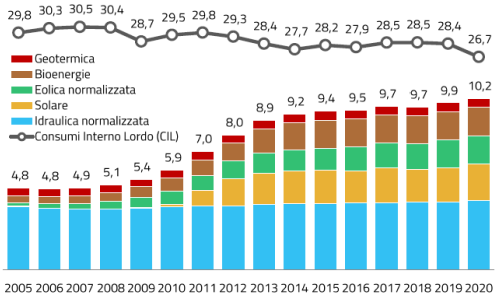


Figure 6: Electric RES by source and gross domestic consumption in Italy (GSE, 2020).

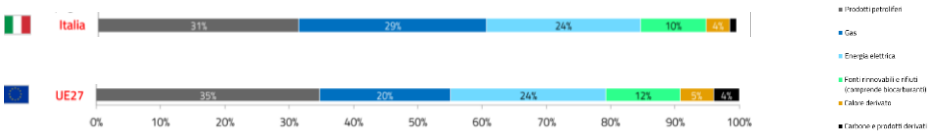


Figure 7: Share of fuels in total energy consumption (GSE, 2020).

Energy guidelines

The European Commission announced the **European framework** for energy and climate policies with a time horizon of 2030. The 2030 framework program aims to enable the EU to address several issues, such as:

- The next step toward reducing greenhouse gas emissions by 80-95% from 1990 levels by 2050.
- The vulnerability of the EU economy to high energy prices and future price increases, particularly for oil and gas.

- EU dependence on energy imports (often from politically unstable regions).
- There is a need to replace and modernize energy infrastructure and provide a stable regulatory framework for potential investors.
- Defining an agreement to reduce greenhouse gas emissions by 2030.

The European Council agreed on the framework for energy and climate policies at the 2030 horizon for the EU, endorsing four critical goals:

1. Reduction of greenhouse gas emissions by a minimum of 40% by the year 2030 in comparison to the levels recorded in 1990.
2. Consumption of renewable energy should be at least 27%.
3. Energy efficiency improvement should be at least 27%.
4. Completing the internal energy market should be supported to achieve a target of 15% of electricity interconnections.

Regarding energy security, the European Council envisioned further actions to reduce energy dependence and improve the security of its electricity and gas supply (European Council, 2014). Italy has set a target for achieving a **30%** share of renewable energy in final energy consumption by 2030 through its National Integrated Energy and Climate Plan (**PNIEC**). However, this target is yet to be revised. In addition, the "Fit for 55" package, a set of proposals to revise and update EU regulations, has made it a legal obligation for the EU to reduce its emissions by at least 55% by 2030. Specifically, promoting renewable energy is targeted to reach at least 40% by 2030.

2.3.2 Overview of the current energy system in Piedmont

The Piedmont Region Energy System analysis has been selected because the proposed meta-plan, in the concluding part of the paper, addresses the case study of the Metropolitan City of Turin. The case study as a **familiar case** for much work carried out during these years and for which we had all the relevant data available. Therefore, as part of the analysis of the “Theoretical Framework”, the in-depth study of the Piedmont region is useful in providing a basis for the following chapters.

Legislative regulation of the energy sector is up to the regions (Art. 117, c. 4), except for that part of the subject matter that is "*national energy production, transportation, and distribution*" (Art. 117, c. 3), among the subjects of 'concurrent'

legislation. In the latter case, it is up to the regions to **legislate**, and it is reserved for the state to determine the fundamental principles. The chapter presents the regional energy balance, describing the main energy flows and the dynamics at work on energy end uses. In particular, the electricity sector is essential for understanding what is taking place on the renewable energy front and the trends in Energy Communities.

The regional energy balance shows a domestic production derived from RES of about 15% of consumption, thus depending about 85% on supplies from outside the region. In addition, a substantial part of dependence on fossil energy sources and natural gas goes through transformation processes before reaching end uses (electricity and heat generation). The final consumption accounts for the private sector (domestic and tertiary) for about half of total consumption, transportation (27%) and industry (23%). The agricultural sector plays a secondary role. All sectors recorded decreased consumption from the previous year (ENEA, 2021). The renewables contributed to final energy consumption of 18.7% in 2019, the highest share ever recorded. Furthermore, the proportion of renewable energy in final consumption is rising.

Piedmont PEAR Regional Environmental Energy Plan guidelines

On 15 March 2022, with DCR no. 200 - 5472, the new PEAR of the Piedmont Region was released. The new PEAR is a strategic planning tool for Piedmont to achieve the EU's Climate-Energy Package 2030 targets. The PEAR objectives apply to all regions and are not 'territorialized.' Starting from the definition of **strategic macro-targets**, the reduction of consumption and the gradual substitution of fossil fuels alongside the increase in the share of renewable energy sources are 'key objectives'. In addition to achieving the two targets (the vertical macro-objectives), implementing several strategies will contribute to maximizing greenhouse gas reductions. In particular, the identification of smart grid models to support the decentralized generation, renewable energy communities, and forms of collective self-consumption; the development of district heating to make greater use of the heat production of existing plants; and innovation and training in the clean economy. These objectives are transposed according to a process of **vertical coherence** by hierarchically transposing the indications at the state level. Thus, the PEAR takes the form of a regional-scale strategic plan having **limited territorial implications**.

Looking at the medium term (2030), the dynamics in place on the leading indicators seem to align with the objectives set by the Regional Environmental Energy Plan, but less if compared with the new objectives of the "FIT for 55" strategy. Targets for renewable resources tend to align with what PEAR has set for 2030 (18.7% in 2019 and 27.5% PEAR 2030 target). Meanwhile, the ”FIT for 55” strategy of 40% by 2030 is much higher than the previous target (32%). For CO2 emissions, the 2019 figure marks a reduction of about 23% from the 1990 figure, in line with the PEAR projection of a -40 % reduction by 2030. Meeting the targets set by the new European "Fit for 55" strategy (-55%) will require more measures and funding to remain consistent.

2.3.3 Role of Renewable Energy Sources

Energy needs are assessed based on the primary energy required for final consumption. Primary energy is the energy available in nature; primary energy sources are fossil fuels: oil, natural gas, and coal. Nuclear: from fission and fusion. Renewable: biomass, hydro, solar, wind, and geothermal.

Renewables are those energy sources that can be considered inexhaustible. The possibility of opting for RES technology systems is linked to each territory's geo-morphological characteristics and climatic conditions. Their accessibility is instead correlated to constraints of a different nature, especially legislative constraints for the territory's environmental, landscape, and cultural protection, to be assessed specifically for each territorial context of reference. Morphological characteristics affect the availability of RES resources peculiar to each settlement context. In addition, some intrinsic characteristics of RES resources, such as discontinuity, make these resources closely related to climatic and atmospheric conditions; this raises issues related to sustainability in harvesting and managing these resources in quantitative and qualitative terms.

Like any human activity, technological systems linked to the use of renewable energy sources also have an environmental impact related to the production processes or the construction of the systems' components. By opting for an environmental impact assessment that considers the entire life cycle, it is possible to demonstrate the sustainability of RES energy production plants, also considering monetary and non-monetary benefits of an economic and social nature.

The transition from centralized to decentralized energy systems

Centralized energy systems are based on a '**one-to-many**' paradigm: a small number of oversized plants produce large amounts of energy to meet the demands of many diverse and geographically dispersed users. The distribution system is one-directional, necessarily ordered, and hierarchical, but also fragile in spatial terms, connection to more remote users, and temporal terms in managing unexpected energy peaks.

A decentralized energy system consists of individual units physically distributed in space, integrated to perform activities in the energy production, conversion, transmission, distribution, and consumption chain effectively. Distributed energy systems present a more significant number of producer entities, homogeneously located throughout the territory, differentiated by type and size of generation plant. Producer entities may coincide with entities that are simultaneously consumers (prosumers), so the distribution network provides for a **two-way flow** of energy. In addition, a shorter length of the energy distribution and transmission networks leads to an improvement in the distribution service, increasing the network's reliability. However, the intermittent and discontinuous nature of RES makes proper planning and design of production facilities indispensable to maintain energy security standards.

Distributed generation incentivizes the use of renewable energy sources since bringing the places of production and energy consumption closer together saves money and makes the investment worthwhile. Consumers whose core business is not producing and selling energy can become producers, opting for RES technology systems characterized by a certain degree of flexibility, modularity, and scalability. The insertion of such production plants within a distributed energy system allows the valorization of energy, also from an economic point of view, favors demand and consequently contributes to continuous technological innovation aimed at increasing efficiency.

In the context of distributed energy systems, energy production, consumption, storage, transformation systems, and diversified energy carriers (electricity and heat) are part of the network. The result is a variegated and complex network, a mass of different kinds of data that, for energy optimization, require an **integrated management** capability typical of IT systems. Smart Grids enable the network to be managed in a 'smart' and 'active' manner, managing discontinuous and bi-directional energy flows. Thus, they eliminate the criticalities typical of renewable energy: better managing peaks in energy demand and maintaining a constant

supply. Therefore, the digitization of networks will be crucial to ensure proper and appropriate energy management using second-generation meters.

A decentralized energy system is applicable on a **large scale**, but as the scale of the grid grows, it entails greater complexity of governance. As far as electrical systems are concerned, at present, there is no need for investment in distribution infrastructures, which are already in place, but in tools and services for managing complex and flexible systems and in a reference legislative and regulatory framework capable of protecting the various players in the system. In the case of Energy Communities, investing in management and control systems for energy flows, such as second-generation meters, and a structure of subjects coordinating operations within the community will be necessary.

From the moment that the individual prosumer has the opportunity to dispose of the energy he produces, each subject can become a node in the network, aware of being functional to the system and contributing to the sustainability of the whole. The **democratization** of energy can be found not only in the shared management of resources but also in the greater awareness of being part of a whole and in increasing local control over resources. Although in different ways, each producer node performs the same function and thus can recognize itself as equal to other producer subjects, implementing fairness and equality and the ability to live in a community, sharing rights, duties, and responsibilities.

Incentivizing decentralized energy systems is essential to achieve sustainability goals, but if applied alone, more is needed to meet current energy demand. In order to meet the national energy demand, these systems must be combined with **energy efficiency** measures aimed at reducing consumption and measures on energy **storage** systems, which allow more flexible management of energy from renewable sources.

Chapter 3

Energy and its relationship with the urban system

3.1 Conceptual development of the research work

At such point in the current research work it is necessary to explain the conceptual direction taken in relation to the research objectives identified in Chapter 1.

Introduced the energy issue and the dynamics at the various scales, the work addresses the issue of energy and its relationship to the urban system. Indeed, the work sets as an overall goal to find the interaction between energy and spatial planning.

The work focuses on the **Italian context**, where energy topics and spatial planning are treated sectorally and is focused on **renewable energy sources** to reduce dependence and the environmental impact of energy. In this work the ECs, newly born in Italy, are seen as an **opportunity** to increase the **integration** between energy and spatial planning. Therefore, in the dissertation work these issues are investigated and organized as follows.

The first section, which provides a theoretical framework, highlights the strategic importance of sustainability in the energy sector. Then, investigates the relationship between energy and the urban system, focusing on the interactions between territory and energy. Chapter three examines the energy planning tools in Italy and their characteristics. Chapter four introduces the concept of energy communities, their history, regulation, and benefits to communities. The exploration of ECs is carried out, in this first part, from a theoretical point of view and then from a practical and applied point of view.

The second section focuses on a practical application. The context of analysis and the objectives to be achieved have been clarified, in this second part the work

addresses methodologies and tool for this purpose. In particular in Chapter Six, describe a methodology for assessing the pre-feasibility of a Renewable Energy Community. This analysis was chosen to better describe **how RECs model work** in Italy. By starting from a small case study of a few utilities, it is possible to observe the energy dynamics involved and the energy indicators that provide the best description of them. Following, in Chapter Seven, a territorial and energy analysis at a vast scale (the Metropolitan City of Turin) was implemented. Following the implementation of the analysis at a local scale of less complexity to a territorial scale analysis that is more complex and multifaceted. This analysis will be fundamental in the final energy meta-plan proposal, providing the **spatial** and **energy knowledge framework** of the case under study.

Following the **quantitative** methods of Chapters Six and Seven, the work introduce the analysis of best practices in Chapters Eight, Nine, and Ten with a **qualitative** methods.

In summary, it is conducted an analysis of the dynamics of an REC, seen as an opportunity to increase the integration of energy and spatial planning, at the local and at the vast scale. The practical analysis is essential to undertake **measurable** and objectively **monitorable proposals**. These chapters identify tools and methodologies for the spatialization of energy to guide decisions in the energy-related policies, laying the basis for the concluding chapter on restyling ordinary planning tools to guide territory considering energy aspects.

3.2 Spatial transformation and energy

Only in 1973, after the first energy crisis following the Kippur War, attention was drawn to the relationship between energy and land management. From then on, the debate on the depletion of fossil fuels considered the relationship between energy and urban systems. In the following decades, energy issues were **only indirectly** related to urban development. First, the physical and structural variables of human settlements that can influence the urban energy system in terms of energy consumption, such as the shape and size of the city, the density of development, the characteristics of the built environment, and its physical and functional forms, and the urban microclimate were considered (De Pascali, 2008). This situation initially led to a debate about the definition of **optimal settlement solutions** identified in urban models (e.g., urban *sprawl* versus compact cities). In general, the scientific community considers the compact model as the urban system with the lowest energy consumption, as well as several sustainable settlement models (*New*

Urbanism, Smart Growth, Car-Free Cities, Low Carbon Cities) that can provide low fossil fuel-dependent settlements by intervening through density and functional mix strategies.

Since the 1980s, when environmental and climate issues have been the focus of much attention, the debate has seen the emergence of community-based and environmentally driven policies, programs, and initiatives that outline the energy discipline in the **urban environment**, addressing the city organism as a whole and triggering the interest of stakeholders in the area. From the first Green Paper on the Urban Environment (COM (90) 2018 final), through the Climate Package (COM (2008) 20) to the latest Comprehensive Plan (COM (2009) 519), the directions of this subject aim to "***move away from sectoralism*** *and turn attention to the* ***cross-cutting nature of energy elements***," meaning the directive aims to ensure the independence and security of energy supply and to develop energy technologies that contribute to the transition to a sustainable socioeconomic model.

The work of **Ownes** (1986) outlined the theoretical and applied basis of the elements for energy planning in settlements, a precursor to energy issues in planning practice. According to the author, the relationship between energy systems and spatial structure is by the "*energy and development cycle*," which biologically links economic development and energy consumption, and thus the morphological and functional organization of energy elements and settlements. Unconstrained energy sources influence settlements' morphological and functional structure (location, shape, size, density, infrastructure systems, and functional combinations) and the associated socioeconomic dynamics (what initiates and facilitates urbanization). The interaction between the energy system and the urban body regards energy **demand** (mainly indoor comfort and transportation) and energy **supply** and **distribution** (density, layout, and orientation).

Owens defines the energy efficiency characteristics of spatial structures. The most influential characteristics are compactness, land-use integration, concentration of transfers, and, at least in part, self-contained urban units of various sizes and numbers. They define "compact cities", "archipelago patterns", and "linear grid structures" as the main types of energy-efficient spatial structures. An adaptation of the pure compact city concept is the **polycentric** (decentralized concentration) spatial structure, which answers the trade-offs while maintaining the benefits of a single compact city (Holden & Nor-land, 2005).

The debate on the form of cities has led different disciplines to search for urban forms that meet sustainability requirements, evaluating sustainability from different perspectives and approaches. A critical review of these approaches shows a need for more agreement on the most desirable urban form in the context of sustainability. The urban forms identified aim to achieve different goals depending on the context and dynamics. Decreasing energy consumption, reducing waste and pollution, reducing automobile use, preserving open spaces and sensitive ecosystems, and livable, community-oriented human environments stand out. Therefore, defining whether some urban forms contribute more to sustainability than others is related to the context and dynamics under consideration. Many studies have focused on establishing metrics to evaluate sustainable urban forms, mainly focusing on the relationship between urban density, compactness, and sustainability. Some of these studies identify compact cities as more energy sustainable, as they reduce energy consumption in cities, while others highlight their relatively poor ability to use renewable energy sources. Ehsan et al., (2019), for example, show how the results obtained from this work facilitate the identification of optimal planning conditions for the sustainable development of future cities by evaluating a set of density indicators. The identified guidelines recognize that there is no globally accepted definition of absolute optimal density, as it depends on considering different aspects determined by urban policies. Ferdouz and Cochran et al., (2017) examined the São Paulo Metropolitan Region using satellite remote sensing data and landscape metrics, defining a move away from or towards more sustainable urban forms of urban heat island mitigation.

One of the most discussed topics in these articles is the issue of transportation. Lohrey and Creutzig, (2016) explain how the urban transportation system systematically changes sustainability problems related to urban forms, such as greenhouse gas emissions, local air pollution, and congestion. Compact urban structures and intensive development are favorable because they promote more efficient energy use in cities. On the other hand, it takes work to verify a clear relationship between urban structure and transportation system. Some studies have found it to be "weak" or "uncertain" because of the importance of socioeconomic factors and people's attitudes (Næss & Jensen, 2004).

In conclusion, sustainable urban development in land use planning and management has emerged to ensure sustainable future developments. In summary, **multiple visions** exist for the sustainability of urban forms and pathways to create smart and sustainable cities. Critical analysis of these documents, as evidenced by the analyzed studies, proposes qualitative and quantitative evaluation

methods that consider specific characteristics and scales of application. These types of assessments are crucial to guide urban development policies better.

In recent years, an informal, bottom-up approach has developed that directly involves stakeholders in local transformation processes that aim to shift from energy-intensive and highly fossil fuel-dependent models to models that regularly use available local resources. These **informal, bottom-up approaches** are a novel move toward alternative modes of action. For example, post-carbon cities and energy communities can improve the capacity of actors in settlement transformation processes through the active and direct participation of the public rather than professionals. Cities are focal locations of energy demand and thus critical to changing the trend and focal points for targeted action. From this perspective, urban planning is a tool that enables cities to build for the present and, more importantly, to aim for the future. In other words, the plan's purpose is to present an **energy valence**: a set of environmentally sensitive, deeply experimental, and innovative strategies and orientations aimed at integrating energy values into everyday planning practices.

3.3 International movements toward energy transition

After the formal introduction of sustainable development (1987), since 1990, Europe has produced a series of documents and initiatives to inspire sustainable development policies, focusing on the closely related issues of energy efficiency and climate change. The link between energy and cities makes it necessary to address energy issues **locally**— analyzing how Europe and Italy address these issues using the available tools. The leading international strategies for governing the climate transition were indicated and briefly described. At the International level:

Sustainable Development Goals (2015). Defined by the United Nations (UN) in 2015, the SDGs are 17 global goals to improve the planet's quality of human life worldwide by 2030.

Sendai Framework (2015). Agreement to reduce natural and artificial hazards. The Framework includes seven objectives and four priorities.

New Urban Agenda for the **21st Century** (2016). A conference on sustainable urban development. The Agenda, adopted at the United Nations Conference, is a shared vision for a sustainable future.

Paris Agreement (2015 COP21). Mitigation and adaptation for building climate resilient cities. It is an international treaty regarding greenhouse gas emission reductions and finance.

At the European level, the European Climate Strategies:

'20-20-20' Climate and energy targets to Energy Roadmap 2050. The European Union's Strategy toward a low-carbon economy aims for an 80%-95% reduction in greenhouse gases, compared to 1990 levels, by 2050. The document recognizes that renewables and energy efficiency must be more significant in Europe's current and future energy supplies.

The EU Green Deal promotes the transition of energy and climate neutrality to 2050. The Deal aims to transform Europe into a modern, resource-efficient, competitive economy without generating GHG emissions in 2050. The EU Commission proposed reforms to reduce net GHG emissions by 55% by 2030 compared to 1990 levels in climate, energy, transport, and taxation policies.

European adaptation strategy through EU Mission 2021-2027. Smart Cities and Climate Neutral Impact to 2030 (100 cities). The 100 cities participating must sign a *Climate City Contract* - a plan for climate neutrality in all sectors, including energy, buildings, waste, and transport.

REPowerEU. Secure, sustainable, and affordable energy for Europe. After the Russian invasion of Ukraine, the energy market suffered disruptions and difficulties (May 2022), reducing dependence on Russian fossil fuels, reducing energy consumption by 20%, introducing a cap on gas and oil prices, and doubling renewable energy diffusion.

At the National level, we can identify the following national strategies:

National Energy Strategy, National Climate Change Adaptation Strategy (2015) and National Climate Change Adaptation Plan (2019 in SEA). The

National Energy Strategy (SEN) 2017 aims to decrease CO2 emissions by 39% by 2030 and 63% by 2050. The National Climate Change Adaptation Strategy (SNAC) defines a set of sectoral actions: non-structural or "soft" actions, infrastructural and technological or "gray" actions, and actions based on an ecosystem approach or "green" actions. Finally, the National Energy and Climate Plan - PNIEC 2019 - is a strategic plan with targets by 2030.

National Strategy for Sustainable Development (2017). The Strategy declines at the national level the 2030 Agenda principles for Sustainable Development (UN, 2015) according to 5 thematic areas (the 5 P's: People, Planet, Prosperity, Peace, and Partnership) and a cross-cutting area called Sustainability Vectors.

National Recovery and Resilience Plan (PNRR 2021). Strategic plan for the country's modernization through six areas of intervention, supported by a significant amount of funds. Mission 2 -Green Revolution and Ecological Transition- the energy transition is dealt with 69 billion euros, divided into six missions: digitization, innovation, competitiveness, and culture; green revolution and ecological transition; education and research; infrastructure for sustainable mobility; inclusion and cohesion; and health.

Since 2003, the ***Post-Carbon Cities*** program has taken off. To help local communities in the dual challenge of climate change and *peak* oil by defining the post-carbon settlement model. This model assumes precise characteristics: less private car use, functional mix, enhancement of distributed energy production, higher housing density, and use of RES by intervening at the level of land-use government. The theoretical basis of the U.S. *Post carbon cities* shares a similar European initiative called *Transition Town*, an experience of particular interest again from the relationship between urban sustainability and social organization.

Other experiences come from nonprofit organizations, which are also spreading through the adaptation support efforts of some transnational municipal networks (TMNs) such as the 100 Resilience Cities Network (100RC), Local Governments for Sustainability (ICLEI), C40 or the Global Covenant of Mayors for Climate & Energy (GCOM).

3.4 Energy models

Several authoritative studies (Owens, 1986; Owens, 1992) have demonstrated that the most effective means of influencing energy dynamics and related CO2 emissions in the long run is through decisions made in the field of urban planning. These solutions concern land use, public and private mobility design, urban waste management, water supply systems, renewable energy production (planners must find optimal locations by spatial constraints for RES plants and energy storage systems), distribution, green systems, and building design. The unequal distribution of energy demand and sources within an urban area highlights the importance of

understanding the different connections between energy and the specific characteristics of a city. These considerations identify urban **energy mapping tools** as practical support for decision-making and planning (Stoeglehner et al., 2016).

Energy maps aim to characterize specific energy patterns (demand, supply, production, and distribution) through spatial visualization of energy data, support "*informational*" interventions, suggest strategies, and identify the most appropriate priorities and locations for developing local energy sources. Spatialized information helps create a basic understanding of system interrelationships, which helps define a shared vision and goals that can lead to more sustainable cross-sectoral strategic actions (Fremouw et al., 2020).

In particular, energy models are tools that, through the use of databases (used in spatial planning) of different origins and different formats, are modeled, tested, evaluation metrics established, and finally returned to spatial actors so that they can take a look at them through visualization systems that make the return of complex data simple and practical (Figure 8).

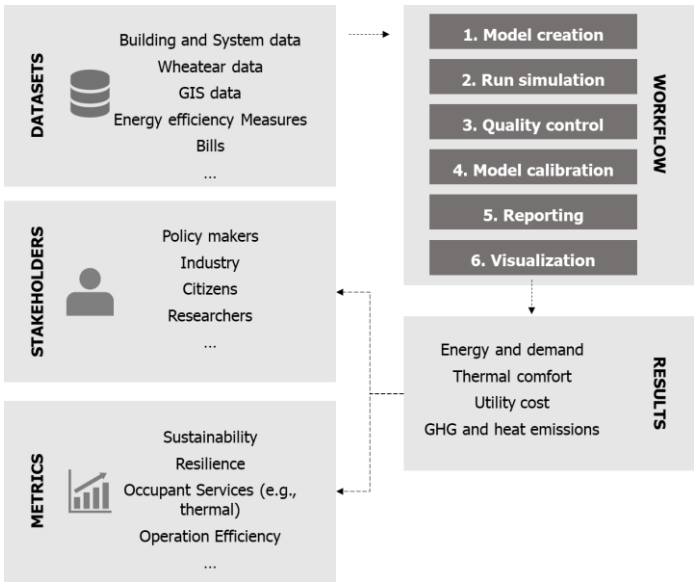


Figure 8: Flow-chart application of urban energy models (Tianzhen et al., 2020).

The urban environment is a box within which several energy conversion processes occur, encompassing different sectors, such as buildings, industry, transportation, and general city infrastructure. Understanding and approaching this complex system involves a **holistic** and **integrated** approach, considering the

exchange of energy flows of different origins. In agreement with the literature, this concept can include the **Urban Scale Energy Model (USEM)** (Sola et al., 2020).

The USEM is a virtual model that provides spatiotemporal resolution of energy flows in territories; it describes a particular energy system and proposes possible strategies to improve its urban energy performance. Virtual modeling of the USEM allows for evaluating system losses, peak loads, shares of unconsumed energy, and the consumer-supplier relationship (Ballarini et al., 2023). The local climatic conditions and urban morphology affect energy consumption and production (Doost et al., 2020). Hence, these models need to consider the context of application. It is necessary to consider different factors at different scales since energy dynamics depend on the interaction between envelope elements, technical systems, building environment, outdoor climate, and human behavior (Mutani & Todeschi, 2020). However, these energy models consider only some of the variables that influence the energy at the urban scale. Designing these models at the urban scale is a complex task, as available data usually lack some details at the building scale; therefore, the goal is to find the **balance** between **model accuracy** and managing large **amounts** of **data** at different scales (Mutani & Todeschi, 2020).

Spatial-scale energy models must manage a large amount of data that could be more accurate and up-to-date compared to models used to assess a single energy system. However, much information is unavailable and generally provided at a different scale. **Place-based models** enable managing information by overlaying databases even at different scales and creating a unique spatial database. In this way, it is possible to quantify consumption related to anthropogenic activities according to variables that describe their extent and intensity. Consumption can then be compared with energy production and the producibility of renewable sources, hypothesizing future scenarios as a function of energy efficiency measures and identifying which energy policies and financial instruments might be the most effective in promoting more sustainable spatial development. Three categories exist in the literature for energy analysis at different spatial scales: top-down, bottom-up, and hybrid models. These approaches aim to reconstruct energy trends (historical, current, and future) while also allowing us to understand how urban transformations affect energy consumption and to assume energy upgrading, promoting sustainable development through renewable energy sources.

Top-down models start with data at an urban scale and, by relating them to climate data, census results, and statistical surveys, make it possible to determine

the average energy data of more specific objects (e.g., buildings). **Bottom-up** models start from specific data of objects and then define energy characteristics on a larger scale based on the experience of the reference sample. On the other hand, **hybrid models** are top-down or bottom-up engineering models that can also simulate future scenarios.

Chapter 4

Energy planning: the framework

In the previous sections, we have seen how the literature recognizes the direct and reciprocal relationship between the dimensions of energy and spatial planning (Owens, 1986). Moreover, several authors consider spatial planning as a means of addressing the challenges of climate change and energy transition (IPCC, 2021; Agenda, 2030).

4.1 European and national documents on energy and urban environment

As highlighted in the previous chapter, there is a link between energy and cities and the need to address energy issues at the city level. Therefore, the paper proposes a review of the literature on the relationship between energy and the urban environment to understand how Europe has dealt with these issues over time. Following there are European documents on energy and the urban environment.

The **1990 Green Paper** on the **Urban Environment** describes the "Urban Environment" problems and comprehensively analyzes the causes of urban decline, highlighting objectives and guidelines for urban improvement.

Agenda 21 (Local) is a document of programmatic intentions and goals for the environment, economy, and society, strengthening the role of social forces and means of implementation. It was signed at the UNCED in Rio de Janeiro in 1992.

The **1994 Aalborg Charter** - European Cities Charter for Sustainable and Sustainable Development. The document sets out a declaration of principle: European cities for a sustainable urban model, promoting a Sustainable European Cities Campaign.

Towards a **thematic strategy** for the **urban environment**, 2004 (COM (2004) 60 and the COM/2005/0718). The European Union establishes cooperation

measures and guidelines to improve the urban environment. These measures focus on exchanging experience and disseminating information to ensure effective implementation of legislation and foster best practices within local authorities.

Sustainable cities: the **Leipzig Charter**. The E.U. proceeds to define an ideal model of a European city for the 21st century and identifies a series of strategies and actions related to a standard policy for urban development.

Climate-Energy Package 20-20-20 to **Energy Roadmap 2050**. The Climate-Energy Package sets targets for reducing greenhouse gas emissions, increasing the share of energy produced from renewable sources, and improving energy savings by 20% by 2020. The European Union's strategy toward a low-carbon economy aims to reduce greenhouse gases by 80-95%, compared to 1990 levels, by 2050. The Energy Roadmap 2050 provides a European regulatory framework.

Directive 2009/28/E.C., promotes of the application of renewable energy sources, establishing a common framework by setting mandatory national targets for final consumption and transport from RES.

The **European Strategic Energy Technology Plan**: Toward a low-carbon Future 2010 and the European Framework Program for Research and Innovation 2014-2020. The SET Plan put technological innovation back at the center of strategies to reduce emissions and accelerate the development of low-carbon technologies.

Energy in the **European Urban Agenda**. The Urban Agenda addresses the problems of cities by creating partnerships between the Commission, E.U. organizations, national governments, local authorities, and stakeholders, such as non-governmental organizations. Together, they develop action plans to adopt more effective laws, improve funding programs, and share knowledge.

The **Covenant of Mayors** and the **Sustainable Energy Action Plan**. The Covenant of Mayors is the European framework for involving cities in the strategy for energy and environmental sustainability, it has been joined by more than 1,600 cities. The Covenant is currently one of the main tools for promoting urban sustainability principles and can act as a catalyst for economic revitalization and improved image of many local areas. It brings added value to the development of the national territory. The project puts in place a bottom-up involvement, providing local governments the opportunity to engage concretely in the fight against climate change.

Renewables Directive RED II (2001/2018/E.U.) deals with the "Renewable Energy Community" (REC). The Directive addresses the "Renewable Energy Community" (REC), a new legal entity with goals of environmental, economic, and social benefits to the community.

Electricity Directive (2019/944/E.U.) defines "Citizen Energy Communities" (CECs) in which citizens, small- to medium-sized businesses, and local authorities cooperate in a local energy supply and consumption system, providing energy efficiency and service management.

At the National level:

Energy regulation of the building sector in Italy and Europe starts from the energy crisis of the 1970s. Europe addressed energy efficiency in buildings with Directive 1993/76/E.C., aimed at limiting carbon dioxide emissions. Since 2002, E.U. laws (EPBD I - II - III and EED) dictate obligations and performance requirements, facilitating energy certification of buildings, renewable sources, and energy diversification. Some important dates for the assessment of energy efficiency levels of buildings in Italian legislation are:

- Anticipating Europe, with **Law 373/76**, introduces criteria for the thermal insulation of buildings and the design of thermal systems.
- **Law 10/91** defines the design methods and management of the building system about system.
- Beginning with **Legislative Decree 192/2005**, the transposition of EPBD European Directives started.

The first national **renewable energy** incentive was the CIP6/1992 resolution, which awarded economic compensation to electricity producers from renewable sources. Then, between 2005 and 2013, five "*Conti Energia*" aimed at photovoltaics, incentive programs in financial contribution for 20 years for each kWh of energy produced. Such convenient tariffs created speculation, transforming agricultural fields and landscapes into photovoltaic panels. The Renewable Decree (Legislative Decree No. 28/2011) adopts Directive 2009/28/E.C. and establishes the institutional framework, tools, and incentives for achieving the 2030 renewable energy targets. This decree stipulates that new buildings or buildings undergoing major renovation must include energy production systems capable of drawing at least 50% of the energy consumed from renewable sources.

This review emphasizes the direct relationship between energy and spatial planning and how spatial planning can help address climate change and energy transition in Europe and Italy.

4.2 National, regional, and municipal energy planning

The following chapter reviews Italian energy planning tools at different scales.

Complex programs: Integrated Intervention Programs (IPPs), Urban Renewal Programs (PRUs), Urban Renewal and Sustainable Land Development Programs (PRUSSTs), and Neighborhood Contracts (CDQs). Other financing forms exist for projects, such as Urban Transformation Companies (STU) and project financing (or General Contractor). Within the framework of Complex Programs, Territorial Pacts represent the legislative instruments of supra-municipal scope that can interact with local investors, activating mechanisms for sustainable growth.

National level plan, the primary energy policy document is the National Energy Plan (PEN), which defines energy policy goals and priorities. The implementing instruments of the PEN are Law 9/1991 and Law 10/1991, which also indicate the bases of energy planning at the local level (regional, provincial, municipal).

Regional level plan: The Regional Energy Plans (PER) related to the use of RES, and as indicated by Law 10/1991 (Article 5 – Regional planning), must contain energy balance, identification of territorial energy basins, the location and implementation of district heating plants, identification of financial resources, formulation of objectives according to intervention priorities, and the procedure for the identification and location of plants for the production of energy up to 10 MW electric.

The **Intervention Program** at the **provincial level** (Figure 9): The Territorial Coordination Plan of the province is the implementing reference of the PER, particularly for energy-saving and RES use (Dlgs 112/1998). The provincial administration, through the PTC, indicates the priority urban areas for intervention (maximum demand, maximum level of emissions); the municipalities where and in what portion it is most effective to intervene on public and private buildings); the municipalities where and in what portion it is most effective to intervene with district heating policies.

Municipal plan, at the urban scale, the Municipal Energy Plan (PEC) must integrate with other spatial planning tools, all flowing into the PRG or PGT, depending on the region. Mandatory energy plans for municipalities with at least 50,000 inhabitants must be more credible in associating energy intensity with the number of inhabitants. Integrated planning is already implicit in Law No. 1150/1942 governing PRGs and Law 1187/1968, which lists specific PRG/PGT contents. These planning documents aim to define and plan a strategy of interventions on the territory to develop an efficient local energy system that is consistent with the leading local socioeconomic variables that must present consistency with the Regional Energy Planning (PEAR). They contain energy analysis of the local territory, energy balances, goals, scenarios, actions, and monitoring.

Participatory choices: With Local Agenda 21 (processes that start from the bottom based on voluntary choices), actions and guidelines arise within forums that are participated in by local actors.

Three-year planning: In the public sphere with the entry into force of Law 109/1994 and its implementing regulation (Presidential Decree 554/1999), the phases preceding the design activity have been identified as follows: the planning activity and for each intervention, the Preliminary Design Document must be prepared (Article 15).

The **Building Regulations** (RUE): It is the tool of building rules that can manage and integrate purely architectural and building indications with technical-operational ones related to energy efficiency. The minimum requirements included in the RUE can determine the choice between intervention alternatives shared with all the actors involved in the planning process. With Law No. 1150 of August 17, 1942 (Urban Planning Law) in Article 33, the contents and rules of integration with the PRG were defined. Today, the Building Regulations are regulated nationally by Presidential Decree 380/2001 as amended in Article 4. In urban planning, some regions have ratified laws defining the rules to be applied. It is a purely technical instrument, limited to technical aesthetics, sanitation, safety, and livability regulations for buildings and their appurtenances. The role of municipalities is of four types:

1. **Regulation**: drafting energy-environmental annexes.
2. **Control**: Assessment and inspection of building interventions and imposition of penalties.

3. **Information**: Information gathering and promotion of information campaigns.
4. **Incentives/Facilitation**: (e.g., reduction of urbanization charges).

Introducing minimum quality performance levels is essential for achieving the RUE objectives. The scope is that new buildings and existing buildings undergoing renovation or extraordinary maintenance. The regulations distinguish between mandatory requirements, which define a minimum level of energy and environmental quality to be compulsorily achieved in each intervention, and incentivized requirements, which are not prescriptive but freely chosen, associated with scores related to the degree of performance achieved and incentivized with measures within the framework of the regulation of concessionary charges.

Moreover, it presents an effective tool for regulating building transformations according to environmental compatibility and energy efficiency criteria: the "**Energy Annex**" form helps to provide further flexibility to the regulatory tool, allowing easy and continuous updating of performance and technological parameters. The contents that the Annex provides are operational rules of a performance character or relating to specific requirements that can be of a mandatory or optional character. Each article describes the qualitative benefits of the interventions and the verification and control activities that the Municipal Administration will implement.

This tool can be applied on a vast scale by creating guidelines for updating municipal building regulations sustainably (Vaccaro, 2016). Could, therefore, provide municipalities with the main directions of "*sustainable building*." When creating guidelines for revising municipal building regulations, it is crucial to consider the general technical and operational contents suitable for different regional conditions. However, for these regulations to be fully effective, they must often be adapted to specific conditions.

In **conclusion**, the possible interactions between the tools of spatial planning and those of energy planning can be schematized as follows (Figure 9). The scheme, proposed by Dall'O' and Galante, 2009, highlights how the Building Regulations are the tool that best interacts between the two levels of planning. From this perspective, Building Regulation is the tool that better integrates energy and spatial planning.

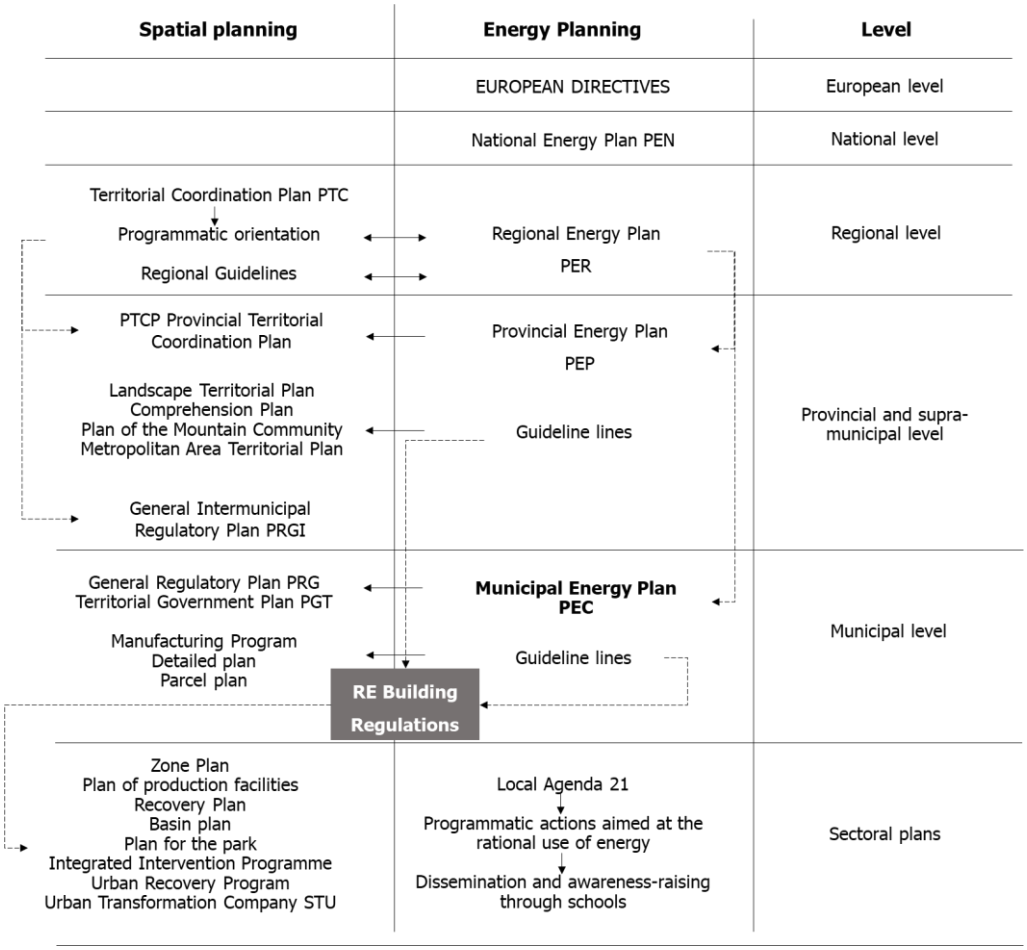


Figure 9: Outline of possible interactions between land use and energy planning tools (Dall'O' and Galante, 2009).

The first agreement between energy and spatial planning coincides with plans post **National Law 10** of **1991**, a Law still in force that attempts to introduce elements related to energy-related urban planning. Municipalities with a population of 50,000 or more are required to develop an energy plan within PRG. The Law hastily and vaguely defines the minimum contents for implementing the plans, leaving the specifics to a series of executive decrees that were never issued.

Law 10/1991 was innovative, but its complete and best implementation has been "betrayed" (Faragazzi & Fanfani, 2012). Energy issues have yet to be considered in the planning stage, let alone integrated. Because of these shortcomings, administrations have often avoided the obligation to establish such a system or have acted with full "interpretive autonomy." The plans have thus taken on a highly **sectoral character** that is difficult to integrate with ordinary urban

planning. With the enactment of Law 10 of 1991, sectoral planning was significantly reduced. This was followed by developing the Municipal Environmental Energy Plan (PEAC), which incorporated environmental externalities into the energy sector. Despite the great potential to combine energy and environment, the integration of energy and spatial planning remains unsolved: the PEAC tends to be a "flagship environmentalism," and the planning process does not go beyond the numerical and design phase, consequently **ignoring** the **spatial application** part, and the monitoring phase (De Pascali, 2021). The energy plan and the environmental plan are almost interchangeable in terms of settlement considerations. Combining the energy element with the environmental element does not change the direction of the path but rather contributes to its complexity and the near impossibility of integrating it into ordinary comprehensive planning.

More, recently the **regulatory gap** has became a significant **opportunity** thanks to the European voluntary initiative "Covenant of Mayors" in 2008. With full legislative and operational autonomy, thanks to the flexibility of urban planning tools (through Title V reform), the way is being open to a "**new generation**" of energy planning that is strongly interdisciplinary, multipurpose, deeply experimental, and innovative (Alberti & De Ioris, 2014). Planning practices thus contribute to including energy elements in managing local transformations and forming a new season of urban energy planning. This expression refers mainly to the good practices that have emerged in **Emilia-Romagna**, which have incentivized the evolution of sectoral planning, starting from a cognitive framework to including energy issues in the normal planning process. In this way, energy anticipates the entire planning process, establishing a correspondence between the energy supply and demand system and local demand and regulating local planning and interventions at all levels.

Traditional land management tools do not adequately address the real needs of cities, and a reform process needs to be initiated, considering different aspects and sensitivities to facilitate the transition to rational and shared planning and strategies that consider the changing world. The search for new ways, possible practices, and highly experimental and innovative approaches has been made possible by the reform of **Title V** and the **administrative simplification** of the planning process. The complexity and importance of urban energy offer an opportunity to recognize the sustainability and subjectivity of living and to draw guidelines for restructuring urban planning. The "Urban Energy Plan" contamination has been made possible by **new regional legislation** and an initiative launched by the European Community **Conference of Mayors**. These two developments are crucial

in meeting energy and planning issues (De Pascali & Bagaini, 2019; Alagna et al., 2021).

In particular, regions have engaged in legislative regulation, codification, and reorganization of regulations in the energy sector. Therefore, regional government planning and technical tools are directly involved, referring to overall regional and city planning. The "Regional Energy Plan" and "National Energy Plan" are regional energy policy and planning initiatives, and municipalities are responsible for measures and criteria for urban energy rights.

The second incentive came from the Conference of Mayors, an initiative that addresses urban areas with the highest energy consumption. Commitments required after signing the Covenant are:

- the preparation of an emissions inventory,
- drafting and implementing a Sustainable Energy Action Plan (SEAP),
- regularly monitor the plan's effectiveness (evaluated directly by the European Community biennially).

Defining a set of objectives aims to **mitigate sectoralism**, awakening stakeholders' attention regarding land management tools.

Based on these two initiatives, the energy plan took on a new form, the "Urban Energy Plan." However, many administrations have chosen a different approach and tools, in which energy elements have become synonymous with varying **degrees** of **cogency** and **action**, focused only on the built environment rather than a holistic approach to planning (such as the RUE). As a result, the process returned to the beginning, and the two issues came into conflict.

4.3 The role of land use planning in the energy field

This chapter discusses the **evolution** of **energy plans** over time. They are starting with the "**first generation**" plans (De Ioris, 2014; De Pascali & Bagaini, 2019) as those issued by municipalities that adopted Ln.10/91. A high sectoral and specialized focus characterizes them, and they are entirely disconnected from spatial planning. These plans look at accounting for the energy flows of the area involved. Because of their high degree of interpretation in their application to energy management, they were not suitable for the traditional planning process and, over time, were abandoned; **PEC**s have gradually undergone a process of

contamination due to the growing environmental consciousness associated with the 1992 Rio Conference and the spread of Local Agenda 21. Environmental issues take on particular weight in the plan, as they are closely related to energy uses; thus, the PEC becomes the PEAC Municipal Environmental Energy Plan. However, the issue of integrating energy into spatial planning remains unsolved; the PEAC has become a banner of environmentalism; the planning process does not go beyond the numerical proposal phase, neglecting the application part and the fundamental phase of monitoring the action and effectiveness of the plan.

Then, the "**new generation**" plans (De Ioris, 2014; De Pascali & Bagaini, 2019) are instruments characterized by flexibility, awareness, and participation. Regulatory gaps and the flexibility of conventional urban planning tools become opportunities. In particular, the reform of Title V, the principle of subsidiarity, and reforms to simplify the planning process introduce new elements in conventional urban planning. The main goal is to reduce emissions and, at the same time, respond to new urban needs. This new multi-sectoral and multi-purpose planning aims to find the link between energy and land-use planning, fostering an interdisciplinary approach and thus enabling the introduction of tools, procedures, and methods that link urban planning and citizenship.

Finally, the **Urban Energy Plan** is the new face of energy-oriented planning. The essential elements are **structural invariance**, and the declinations assumed in urban planning discipline are **hybridized spatial partitions** and **degrees of cogency**. In particular, literature (De Ioris, 2014; De Pascali & Bagaini, 2019) identifies the plan features and recurring parameters that must coincide in an Urban Energy Plan: **regional** energy-specific legislation; **multiple** plan objectives (environment, settlement, energy); definition of **hybrid units** of intervention. In order to guarantee the success of the plan, we need to include the following supporting conditions.

- The possibility of placing the energy parameter alongside **ordinary planning tools**.
- Scheduling of interventions according to **energy scenarios** (definition of qualitative and quantitative development of the area).
- Tools and procedures for **monitoring** interventions to evaluate the plan's effectiveness.
- Creating **public-private partnerships**.

Conventional planning tools need to address a ***restyling*** of the energy plan concerning the **methodological level** (the process of formation and management of the plan) and the **structural level** (elements that condition the planning process).

Energy-oriented building regulation tools (e.g., RUE) slow down the process of convergence between energy and spatial planning, as they focus only on the building stock and thus ignore the multidimensional energy perspective. Instead, we must look to innovative and experimental methodological practices that overcome the sectoriality of tools.

4.4 Characteristics and critical issues of instruments in Italy

The Italian case highlights that the inefficiency and lack of integration in urban energy planning are only partially due to the nature of the plan itself. According to De Pascali & Bagaini (2021), Law No. 10/91, which regulated urban energy planning, has gradually lost its relevance and has been replaced by the SEAP. However, the limitations of Law No. 10/91 have been identified in the SEAP, which suggests that the problems in urban energy planning are not necessarily caused by the plan but instead by the implementation and enforcement of it. The **lack** of **integration** of energy strategies into spatial planning significantly affects the effectiveness of the results (Zanon & Verones, 2013). The main limitation is the need for a more **strategic** and **long-term vision**. The complexity of cities makes it difficult for local governments to implement concrete actions. In addition, there is a preference for adding policies and plans, without coherence and integration, to an already congested regulatory system rather than reforming existing ones. Finally, there is a trend toward "green" marketing- individual actions or demonstration projects (De Pascali & Bagaini, 2019). In summary, the main critical issues identified in the literature of energy planning in Italy are the following:

- **Lack** of **responsibility** of **public authority**. Lack of local government expertise and financial resources to deal with atypical planning tasks and the existence of strong political leadership. Lack of professional, technical, and political support (Lombardi et al., 2010). Last but not least, lack of appropriate institutional framework.
- **Ineffective decision-making processes**. The way urban planning processes are structured is another aspect of the problem of efficient

decision-making (Balducci, 1991). Energy policy and planning are not integrated with land use planning. Mazza (2004) highlight issues related to the actors mobilized, the resources available, and how the actors interact with each other.

- **Lack** of **shared** and **long-term tools** and **strategies**. The wrong choice, or lack, of local policy tools, can be a decisive factor in the success of public interventions. Indeed, this influences implementation strategies. In addition, inadequate administrative processes of resource allocation lead to the implementation of vertical project-funded interventions without a shared strategic vision. Urban policies should include a strategy for energy transition to achieve more sustainable urban development. The urban planning system needs a strategic dimension focusing on sectoral actions with a short-term vision.

4.5 Perspectives of Energy Planning Tools

The **Territorial Energy Basin (BET)** represents the tool to achieve energy saving and RES promotion at the local level. There is no clear and agreed definition but rather a shortlist of possible interpretations. According to Law 10/91 (Article 5) and the manualistic studies that followed it, defining a basin means identifying the users' characteristics, size, needs, and energy demands, as well as outlining economic issues. Administrations, therefore, must interpret the territorial partition as outfits that need a collimation between energy demand and supply. Macro indicators should be identified and integrated into the planning process. Since each territory has its peculiarities, the partitions cannot be pre-established, let alone standardized, but somewhat flexible and linked to the intrinsic characteristics of the territories dictated by the development potential that local resources can offer.

According to these assumptions, PRODEM (2006) (Alagna et al., 2021) represents a best practice that describes and optimizes the territory according to its energy vocation. The **energy planning strategies** are structured through the BET, homogeneous territorial areas. In addition to a descriptive-interpretive function of the relations between energy and territory, they take on a **programmatic** role: regulatory addresses. Different is the definition proposed by the PEC of Bologna (2007), where the Urban Energy Basins represent contiguous areas, **homogeneous** from a purely **planning** point of view (natural and physical infrastructural elements) but partly also from an energy point of view, as the most energy-intensive places, therefore priority in the overall redevelopment of the

territory. Despite their vague and uncertain definition, energy basins show great potential in energy and land use planning.

The **Urban Building Regulations (RUE)** have experienced wide use supported by the consensus of building operators. The approach connotes considering the energy variable in a systemic and multiscale way because the focus is on the building scale alone. The instrument is **limited** in its operation to **new buildings** and those subject to new building conversions (De Ioris, 2014). Since it cannot intervene in the existing building stock, which is highly energy-intensive due to construction techniques and materials, the RUE can minimally affect the overall budget. Promoting and defining sustainable and bio-architectural construction methods, the tool nonetheless has the merit of stimulating operators in bringing innovation to construction. A system that rewards **volumetrically only** annuls the positivity of the structural arrangements put in place to reduce the dissipation of energy resources; on the contrary, it contributes to the consumption of land and local resources. The RUE season has activated a methodology of compensation where sustainable building interventions are rewarded even with volumetric interventions. There are better paths for energy-aware land transformation than this attitude. Despite this, legislators are still focused on adapting and verifying the building's energy parameters.

Thorough ***restyling*** in the architecture and methodological approach of ordinary planning tools makes the land-use government process less impermeable to the energy component. The Urban Energy Plan includes energy valence in the formation process. The first elements characterizing the new plan are (De Pascali et al., 2014; De Pascali & Bagaini, 2019):

- An **appropriate spatial scale** needs to be determined where the significant dimension is the **vast area**.
- A **reference spatial partition** suitable for interacting the two disciplinary contributions should be established. This partition should be a guide to plan choices.
- The **energy component** must be **integrated** into the plan between the different components.
- The **public-private relationship**, the consequent role of local government, citizenship, and interested stakeholders need to be considered.

According to the literature analysis, there is a requirement for innovative spatial and urban planning methods and procedures, along with the development and implementation of novel approaches and tools to move beyond the building scale and focus on the urban and **territorial scale** (Zanon & Verones, 2013; De Ioris, 2014; Alagna et al., 2021; De Pascali & Bagaini, 2019). The theme of the **territorial energy basin**, referred to as the territorial plan, is exciting to investigate, finding articulated relationships between energy and spatial transformations. The conjunction of the relationship between energy and spatial transformations can become a **structural guiding element** in the production of the comprehensive plan, considering the ink between the distributed energy model and inclusive social models of development (e.g., Energy Communities). In fact, implementing a democratic and shared energy transition requires the support of the **local community** (Bulkeley & Fuller, 2012; Goedkoop & Devine-Wright, 2016). Implementing a socially just energy transformation requires the active participation of communities, making them active participants in new renewable energy projects (Rescoop. eu).

Chapter 5

Energy Communities

5.1 History of Energy Communities

We have been hearing about energy communities in recent years, with some States having already integrated them long ago and others having just discovered them, as in the case of Italy. Energy communities are the optimal choice for meeting stringent energy sustainability goals involving the collaboration of local communities. Social involvement makes it possible to consider energy not as a due commodity but as something to be managed, saved, and used.

The "Renewable Energy Communities" (RECs) provided by the European **RED II** Directive (2018/2001/EU), thanks to the **Milleproroghe Decree 162/2019**, have been converted into Law No. 8/2020 of February 28, 2020, and subsequently by **DLgs 199/2021** and **DLgs 210/2021**. In November 2023, the new **RED III** Renewable Energy Directive - Directive 2023/2413 - was published, modifying Directive 2018/2001. This last Directive aims to simplify procedures for obtaining permits and sets the ambitious goal of a 45 % (previous 32%) share of renewable energy to be achieved by 2030.

Several energy communities and cooperatives in Italy emerged from the first decades of the 20th century. Some examples of prototype energy communities, mainly located in the northern area. Italy has more than a hundred historical communities, some older than a century. The model is not legally reproducible, but they are interesting case studies showing the experience's positivity. The number of these initiatives still needs to be more significant to initiate a process on a larger scale. However, in recent years, the birth of these cooperatives has increased radically, a positive sign of people's increased interest in this new form of energy. In this sense, the European Union is promoting the development of energy communities and betting heavily on this new energy management model.

5.2 What is an energy community?

"Energy communities are unions of users located in homogeneous areas, cooperating to enhance the self-produced and self-consumed energy from locally available renewable sources". A coalition of users voluntarily adheres to a contract to produce, consume, and manage energy through local facilities. ECs address the individual involved in energy exchanges by making the user aware of energy management and thus also make the individual achieve a **sense** of **responsibility** with cultural value. How is it possible to create an energy community?

- At the **individual** level: in individual self-consumption, the citizen (*prosumer*) owns a renewable energy plant and self-consumes the energy he or she has produced.
- At the **collective** level, collective self-consumption is achieved by a plurality of consumers located within a building (e.g., condominium) where one or more plants are powered exclusively by renewable sources.
- At the **community** level: In the energy community, several parties (*prosumer* and *consumer*) over a given territory participate who produce energy with RES plants intended for their consumption.

The term "*prosumer*" describes a user who goes beyond the simple role of a passive *consumer* and actively participates in the different stages of the production process. Considering a defined aggregation of different users (domestic, municipal, business), whether they are *consumers* or *prosumers*. The energy produced by the set of facilities is made available to members who can collectively self-consume the energy instantaneously or store it. Excess production can be fed into and sold on the national grid, as the grid-connected condition ensures grid withdrawal when needed. Collective self-consumption (or "shared energy") is, therefore, the share of energy produced by the set of RES plants and withdrawn by the set of members, calculated at each hour of the day.

In Italy, when considering the **legal terms**, energy communities can be formed as Consortia, Cooperatives, or Associations. The members who can be part of these legal forms are private citizens, public administrations, and companies (whose primary business is not energy), which can be consumers and prosumers. The community must be a nonprofit organization: its primary goal is not to produce an economic return from its members.

5.3 Regulatory framework

Energy communities are aggregations of energy end-users who, through voluntary membership in a contract, work together to produce, distribute, consume, and manage energy through one or more local energy facilities. As part of the Clean Package (2016), the Renewable **RED II** Directive (2001/2018/EU) addresses the "Renewable Energy Community" (REC), a legal entity committed to providing environmental, economic, and social benefits to the community through the production and sharing of renewable energy. It shares principles with "Citizen Energy Communities" (CECs), defined by the **Electricity Directive** (2019/944 EU), in which citizens, small- to medium-sized enterprises, and local authorities cooperate in a local energy supply and consumption system, providing energy efficiency and service management. In November 2023, the new RED III Renewable Energy Directive-Directive 2023/2413 was published, amending Directive 2018/2001.

The Piedmont region in Italy was the first to promote the Energy Community. They gave it a broad and flexible definition to implement it at different scales, including territorial (L.R.12/2018, D.G.R.18-8520/2019). Today, the Piedmont region law and the idea of an energy community are surpassed in the Italian regulatory framework.

The first transposition of RED II into Italian national legislation (D.L. 162/2019-Art.42bis, L.N. 8/2020) launches an experimental phase on RECs. It introduces the concept of "**Collective Self-Consumption**" as the share of energy produced locally and simultaneously self-consumed by all REC members. The minimum requirements for access to the dedicated economic incentive (ARERA 318/2020/R/eel and Ministerial Decree September 16, 2020). These stringent requirements facilitate the implementation of pilot projects across the country; monitoring of these small-scale applications revealed opportunities and barriers for full REC implementation and suggested adjustments. In addition, 2.2 billion of the PNRR funds will be allocated for RECs established in municipalities of less than 5,000 inhabitants.

According to the transitional transposition of RED II, the REC can involve a limited number of users and small-scale RES installations (200kW) in a minimal area limited by the same low-to-medium voltage (LV-MV) electrical substation. These stringent requirements facilitate the implementation of small-scale pilot projects across the country: their monitoring revealed opportunities and barriers for

full REC implementation, suggesting adjustments. The final RED II implementation reconsiders the aggregation of a more significant number of members in a **larger territory** underlying the same **high voltage** (HV) **substation**. Finally, there follows the inclusion of more significant (**1MW**) and existing RES plants, which necessarily entails reconsidering the terms of access to the economic incentive on collective self-consumption to be updated in subsequent implementation decrees. In addition, already operating RES plants can join the energy community if they are at most 30% of the total capacity under the community.

The latter concept of RECs is close to that desired by the Piedmont Region, confirming the choice of pilot projects in Piedmont. These projects originated in the 2018 regional legislative framework. While providing for implementing small-scale RECs to access the existing economic incentives, they are defining long-term territorial energy planning for the governance of different REC experiments and preparing for subsequent economic incentives. All the laws presented share the concept of RECs as new configurations of energy systems that can offer leverage for the economic development of the territories: the initial investment in RES plants, energy saving, and optimization solutions implies a push towards increased technological innovation, digital infrastructure, and intelligent systems, and a positive return in terms of employment and quality of life, sharing the perspectives indicated by the various national plans (PNIEC, PNRR).

In the transposition of the EU Directive 2001/2018 (RED II) into the Italian regulatory framework that began in December 2019, an experimental phase was opened involving the Regulatory Authority for Energy, Networks, and Environment (ARERA), the Ministry of Economic Development (MISE), and the Gestore dei Servizi Energetici (GSE). In summary, the **framework** of the **Italian legislation** refers to the RED II directive, transposed on an experimental basis through the combined dispositions:

- of art. 42 bis of Law Decree 162/2019 converted by Law 8/2020 (milleproroghe).
- of the regulatory model outlined in ARERA Resolution 318/2020/R/eel.
- of the incentive system defined by the MiSE (Ministerial Decree September 16, 2020).

Article 42 bis defines terms and conditions to activate collective self-consumption. In the end, the implementation of Directives 2018/2001 and

2019/944 was done with Legislative Decree **199/2021** (MASE), closing the experimental phase and starting the final implementation of collective self-consumption forms. Legislative Decree 210/2021, which implements EU Directive 2019/944, is linked to this. In this regard, ARERA, by resolution 120/2022, implemented the provisions of Legislative Decree 199 and 210 on self-consumption, and by resolution 727/2022 defined the Integrated Text for the regulation of diffuse self-consumption (TIAD), which applies between March 1, 2023 and the date of entry into force of the implementing dm art. 8 of Legislative Decree 199/2021 (Figures 10).

The recent REC Decree Dm 414 of 2023 regulates, by DLgs 199 of 2021, the incentives for electricity produced by renewable energy plants in self-consumption configurations. This Decree closes the experimental phase and starts the final implementation of collective self-consumption forms. The measure aims to encourage the development of 5 gigawatts of renewable energy production facilities by 2027, starting **crucial economic** and **legislative support** for the coming years.

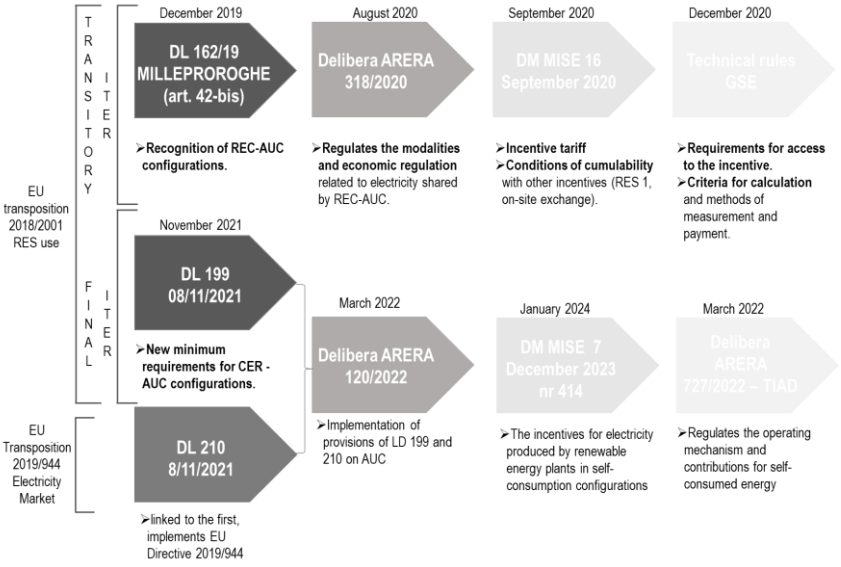


Figure 10: Evolution and references of Italian legislation.

5.4 Environmental and economic benefits

Energy performance indicators

In order to propose changes in energy management at the local level, it is necessary to determine the flow of energy carriers. Local energy scenarios identify renewable

technologies that meet current energy demands and propose options using sustainability indicators (Barragán & Terrados, 2018). In evaluating the potential of the PV-battery system, Luthander et al. (2019) highlighted the importance of the daily and seasonal correspondence between local energy production and consumption. In this context, two indicators express the load-matching potential: the **Self-Sufficiency Index** (**SSI**) and the **Self-Consumption Index** (**SCI**). These indices could evaluate the energy performance of the Energy Community. The self-sufficiency index (SSI) measures the amount of energy consumed locally compared to the total energy consumption. This index is calculated using equation (1). The Self-Consumption Index (SCI) measures the percentage of energy produced from Renewable Energy Sources (RES) consumed locally. The formula for calculating SCI is given in equation (2).

$$SSI = (SC+CSC)/TC \qquad (1)$$

$$SCI = (SC+CSC)/TP \qquad (2)$$

The indices add up the Self-Consumption (SC), Collective Self-Consumption (CSC), Total Consumption (TC), and Total Production (TP) of all members of the Energy Community. The choice of the intervention that best contributes to the achievement of acceptable thresholds for both indices involves an economic analysis and optimal cost assessment.

Figure 11 shows an example of the **energy flows** and **exchanges** for a typical day in REC configuration. Self-consumption is the ability to consume electricity produced by a local plant to meet energy needs. Hourly self-consumption is the share of energy produced by the plant and consumed in the same hour. In order to have an accurate estimate, it is necessary to compare the user's (or aggregation of users') consumption and production profiles and assess the degree of hourly combination for all days of the year.

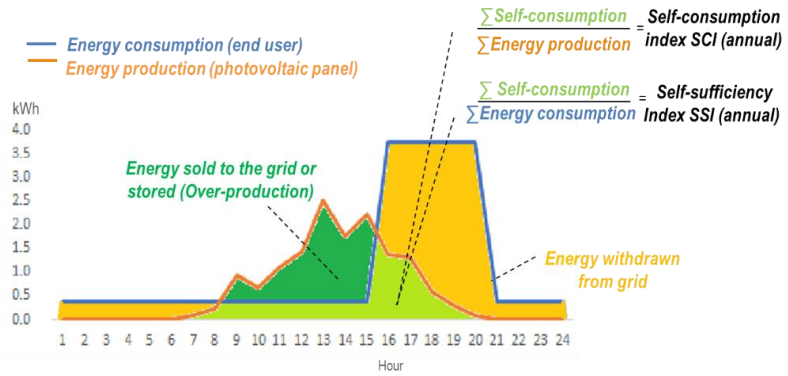


Figure 11: Example of the energy flows and exchanges for a typical day.

In summary, Energy Communities offer a range of environmental, economic, and social benefits. Some of these benefits include:

a) Using local **renewable resources** to produce energy, which reduces the emission of CO2 and other climate-changing gases.
b) Promoting **energy efficiency** both in the production and demand side.
c) Encouraging widespread self-consumption, which benefits the power grid.
d) Encouraging **active**, **voluntary**, and **informed participation** from citizens, businesses, and local authorities.
e) Building **local support** for new Renewable Energy Source plants and related infrastructure.
f) Resulting in **bill savings** due to more direct self-consumption of energy, which reduces variable components of the bill (energy share, grid charges, and related taxes).
g) Generating **income** by producing energy with RES systems due to incentive mechanisms.

European directives specify the characteristics and principles of energy communities depending on national regulation and territorial scope. Common characteristics include:

- Economic, social, and environmental benefits of collective interest before economic profit.
- Promotion of cooperation and collective responsibility.
- Open and voluntary participation;
- Democratic governance, equitable representation of stakeholder types.

This analysis shows that this aggregation requires a **multidisciplinary** approach encompassing technological, economic/financial, legal, environmental, and social considerations. Energy Communities involve individuals in energy exchanges within a community, leading to greater awareness and responsibility towards energy consumption as a limited resource. This increased sense of responsibility has cultural value. Additionally, ECs can help combat **energy poverty** by providing lower-cost energy and enhancing accessibility and affordability.

Chapter 6 Practical analysis

Prefeasibility assessment of a Renewable Energy Community

6.1 Methodology of calculation

The following sections present the pre-feasibility analysis of the REC project, based on the work published in Mutani et al., 2021. The analysis aims to identify the most optimal group of potential REC members by considering the types of consumers and the availability of RES resources for local energy production. The project aims to comply with regulatory requirements and bring energy and economic benefits to all members. The report will detail the energy self-consumed collectively by all members and the economic incentive conditions provided by the MISE decree (2020). The technical rules of GSE and ARERA present in the year 2021 will be followed.

The technical and economic feasibility analysis was conducted for a municipality in the Metropolitan City of Turin, the municipality of Villar Pellice. The analysis was divided into three steps:

1. Defining hourly **energy consumption** and **production profiles** for each REC member based on the end-user category and RES technology system.
2. Evaluating **energy balance** and performance using a set of energy flows and indicators to compare all assumed scenarios.
3. Considering investment costs, energy costs, and payback time with a **life-cycle approach** to compare different intervention scenarios.

Energy data source

The municipality's annual and monthly energy consumption data refer to 2017 and come from the SIATEL database. Thanks to the SIATEL telematics system, it

was possible to consult the financial administration's database on the energy expenditure of the municipality's different categories of end users. Monthly and hourly energy data of residential users were provided by ACEA Pinerolese Spa, considering a sample of about 425 residential users in the Pinerolese territory. The given data is for a standard residential utility for 12 typical days of the year 2017.

Hourly energy consumption profiles

To calculate the monthly energy consumption of City Hall and the Warehouse, we considered the year's holiday schedule, the opening hours of these facilities, and their usage. We derived the energy profile of Social Housing residential users from annual data provided by the SIATEL database. We evaluated the hourly energy consumption of municipal buildings using available annual and monthly data from the SIATEL database and energy bills. We distributed the monthly energy consumption of City Hall and the Warehouse based on their daily opening hours and usage while considering the year's holiday calendar. The hourly energy consumption of Municipal Public Lighting comes from available monthly data from 2017. We evaluated the hourly lighting profile using the conventional on/off times established for northwestern municipalities, as ARERA (ARG/let/29/08) indicated.

Hourly energy production profiles

The photovoltaic panels integrated into the roof consider the available area, the technical characteristics of the photovoltaic system, and the solar irradiation for the year under consideration to maximize energy production. We used the PVGIS tool, which allows us to calculate the hourly energy production, taking into account several constraints such as location (latitude, longitude, and altitude), radiation database, year of evaluation, type of PV support (fixed, vertical-axis, tilted-axis, and dual-axis), panel tilt, building azimuth, PV technology, and system losses. For this case study, system losses are at 14%. The climate and solar radiation data used are from the PVGIS-SARAH radiation database for the year 2016.

REC configuration

Figure 12 represents the energy flows that result in the case of the REC scenario. Total Production (TP) indicates the total energy produced locally by new renewable energy power plants (RES). At the same time, Total Consumption (TC) represents the energy demand of all members of the Renewable Energy Community (REC). Uncovered Demand (UD) is the energy demand that local generation cannot

meet and must be taken from the national grid. Self-consumption (SC) is defined as the amount of energy immediately consumed by each user in equation.

Collective self-consumption (CSC) is the energy exchanged among members of a Renewable Energy Community (REC). It is the difference between the energy fed into the national grid (OPs) and the energy withdrawn from the national grid (UDs) in each hourly interval.

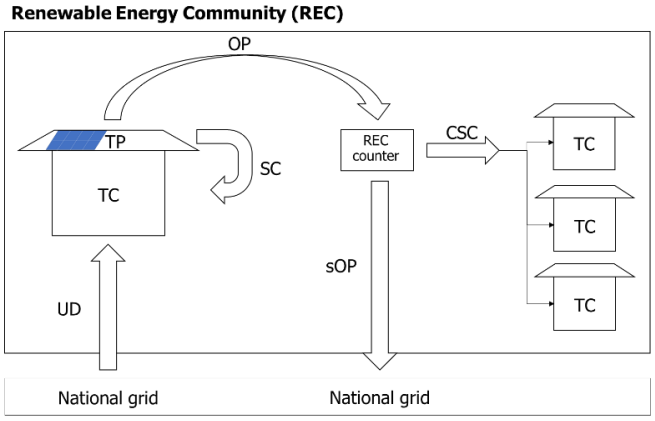


Figure 12: Hourly Energy flows in the REC configuration.

Energy subjects and RES facilities involved in the REC project

In the pre-feasibility study for a Renewable Energy Community project different types of electricity end-users (residential, industrial, and municipal households) were considered members of the REC. In legislation for access to the collective self-consumption economic incentive, all members of the REC (consumers and prosumers) must be connected to the same low-to-medium voltage (LV-MT) electrical substation. Four photovoltaic power generation systems could be integrated with the building roof.

Hourly profiles of energy flows on typical seasonal days

Hourly energy consumption profiles were created for each member of the REC for every day in the 2019 reference year. An hourly consumption profile was then applied to each type of end-user based on their daily activity schedule, using detailed data on their electricity consumption. By analyzing the geometric and solar exposure characteristics of each member's building roofs, we were able to estimate the amount of electricity that could be generated by each user (prosumer) by identifying the number of panels installable, the relative rated power of the

photovoltaic system, and the local hourly solar irradiation conditions for the entire reference year. Figure 13 shows hourly consumption and production profiles for each type of end-user for each typical day in the four seasons of the reference year.

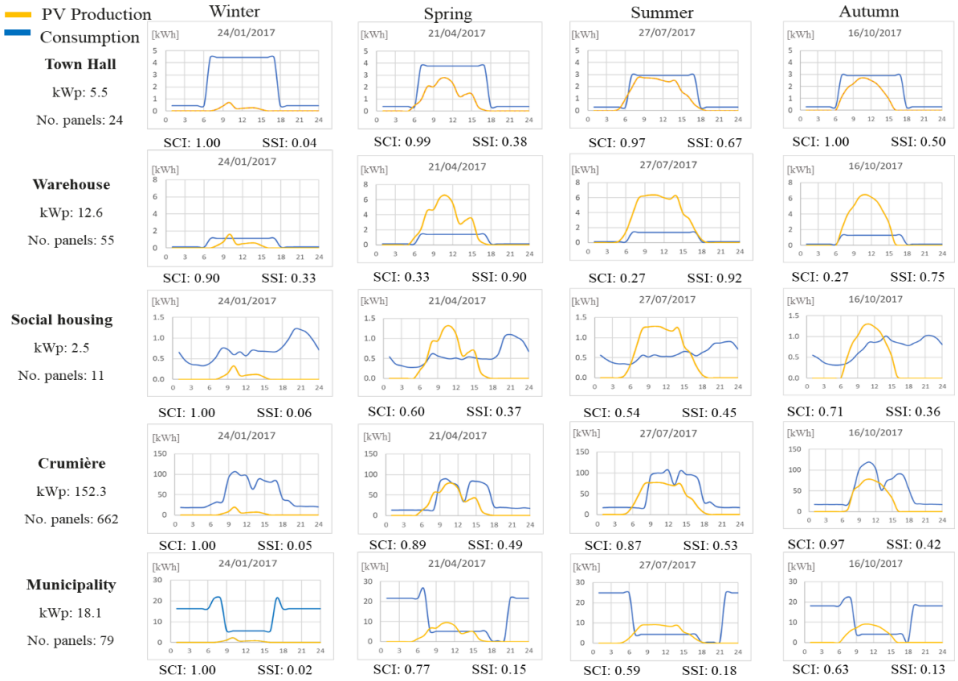


Figure 13: Hourly consumption (blue) and production (yellow) profiles for four typical seasonal prosumer days.

For the REC scenario, hourly energy flows were aggregated for each day of the reference year (Figure 14); in this way, the REC results in a single aggregated, end-user of energy (prosumer) entity.

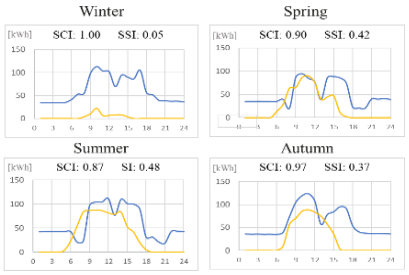


Figure 14: Hourly consumption (blue) and production (yellow) profiles for four typical seasonal days in the REC scenario.

6.2 Life cycle approach based

Energy and economic analysis of the REC scenario

The graphs in Figure 15 show some results of the techno-economic analysis for the REC scenario. The rate (0.11822 €/kWh) of the economic incentive provided by the MISE Decree is applied to this share of energy. To calculate the monthly expenses and revenues, we referred to the energy prices of the reference year 2017. These include the average purchase price of different types of utilities for energy taken from the national grid and the hourly zonal price for selling energy back to the national grid. Finally, the two energy and economic performance indicators were calculated. Specifically, the SCI describes the ability to self-consume the RES energy produced by the Renewable Energy Community; the SSI describes the energy and economic independence of the REC concerning the grid and the national electricity market, both calculated on a scale between 0 and 1.

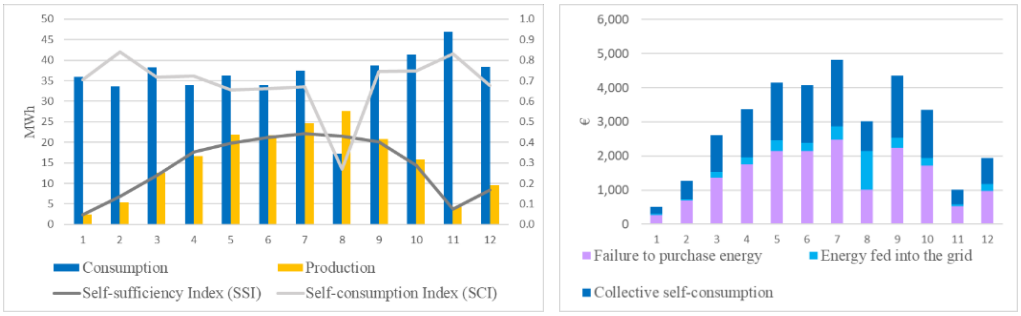


Figure 15: The energy [MWh/month] and economic [€/month] analysis of the REC scenario.

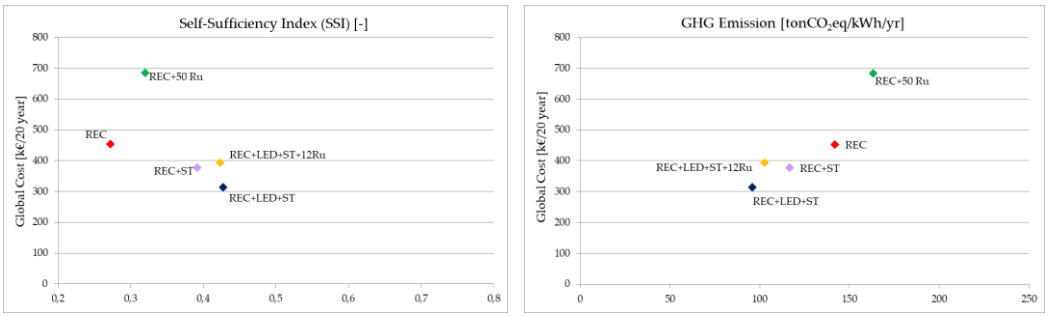
Life cycle approach based

The life cycle approach aims to identify the economic benefits for all stakeholders in each assumed scenario. The cost-optimal analysis allows the economic implications of different types of interventions, defining the cost-optimal level of performance. In the scope of this research, the energy performance evaluation is concerned with the contribution to improving the self-sufficiency and self-consumption indicators. In contrast, the economic performance evaluation concerns securing an economic profit for each energy user. Furthermore, the environmental performance of each scenario defines the annual greenhouse gas emissions (tCO2eq) for the annual consumption of electricity taken from the national grid. The purpose is to determine the interventions that provide energy supply to the most significant number of users at the lowest economic and

environmental cost. To address this, we applied the global cost approach (EN 15459:2007) to each scenario. It calculates the present value of energy costs, including the initial investment cost. Revenues include savings from self-consumption (SC) and collective self-consumption (CSC) since they represent avoided expenditure. The profit (in €/year) of the incentive provided by Italian law (D.M. September 16, 2020) is linked to the CSC.

The overall cost and the payback time consider the initial investment costs and the duration of the MISE incentive on collective self-consumption. The **payback time** of the total initial investment cost is estimated to be around **year 11**, which aligns with the duration of the MISE incentive for collective self-consumption of RECs.

Moreover, the analysis (Figure 16) on the comparison of the scenarios and the REC configuration of the global cost related to the Self-Sufficiency Index (SSI) and the GHG Emissions, shows that aggregation of several utilities, combined with energy efficiency interventions and storage systems, can increase energy self-sufficiency reducing energy emissions.



(a) (b)

Figure 16: Comparison of the scenarios and the REC configuration of the global cost related to the Self-Sufficiency Index (SSI) (a) and the GHG Emissions (b).

6.3 Results and conclusions

The methodology presented in this chapter helps evaluate the effectiveness of REC incentives from the perspective of energy security and cost-effectiveness. The analysis shows that aggregation of several utilities, combined with energy efficiency interventions and storage systems, can increase energy self-sufficiency. However, the use of batteries incurs high economic and environmental costs.

It is essential to promote the implementation of economic incentives that stimulate end users to adopt energy efficiency measures in a coordinated and collaborative manner. The place-based approach allows the identification of scenarios using different aggregations of end users to guarantee the most economic and environmental benefits. The results obtained can provide **technical support** to policymakers.

In conclusion, the REC results in **energy** (increased self-consumption and self-sufficiency), **economic** (shorter payback time), and **environmental** (reduced CO2 emissions) **benefits**. The REC achieves maximum economic benefit by maximizing the collective self-consumption of energy. To optimize the exchange to be rewarded, the basic strategy is to carefully choose members of the REC to have complementary production and consumption profiles. Installing storage systems allows the energy produced to be shifted over time, making it available to REC members and economically advantageous. Including other consumer entities in the REC maximizes self-consumption without incurring additional investment costs. In addition, the combination of energy efficiency and optimization interventions ensures the highest energy and economic performance levels.

Energy communities represent a significant shift in energy production and distribution strategy. Instead of treating energy as a commodity to be bought and sold for profit, it is a primary good of common interest that can be self-produced and exchanged locally as much as possible. Although technical problems may arise, the most significant difficulties are bureaucratic and regulatory**.**

To summarize, this work emphasizes the significance of considering both the **temporal** and **spatial dimensions** while dealing with Renewable Energy Sources regarding energy exchanges in Energy Communities. Hence, it is crucial to consider these two dimensions while developing a new energy plan for the next generation.

Chapter 7

Spatial energy analysis

7.1 Methodology

The following sections present the spatial energy analysis based on the work published by Mutani et al., 2020. The development of Urban-Scale Energy Modelling (USEM) is increasingly attractive in terms of impact on assessing energy efficiency and energy productivity measures in urban environments. These models help investigate energy efficiency solutions and the possibility of installing RES plants, leading to more effective energy demand policies and management.

Territorial-scale energy models have to deal with a vast amount of data, usually available in different formats and levels of accuracy. Much information is often unavailable or is provided on a different scale. Therefore, obtaining some information through modeling and assumptions is only possible. For instance, models based on Territorial Information Systems help manage information by overlapping the databases, even at different scales, to create a single territorial database. This approach allows quantifying the consumption in different areas based on variables that describe their size and intensity. Additionally, it provides data on renewable energy sources' production and potential production. It is also possible to predict future scenarios to identify the most effective energy policies and financial instruments that can promote sustainable development of the territory.

This model follows a **top-down** approach, starting with information at a larger scale, such as municipal, regional, or national level. The model uses Geographical Information Systems (GIS) to manage information from multiple sources. In summary, Figure 17 displays the procedure for constructing the energy models presented in this thesis.

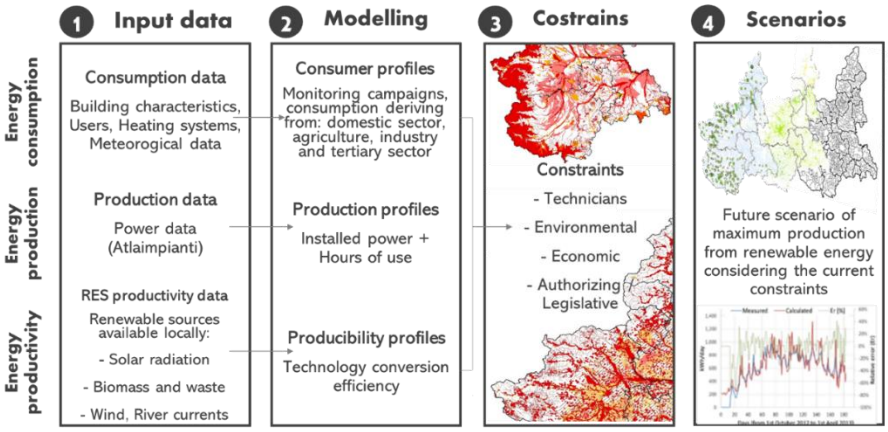


Figure 17: GIS methodology of energy consumption, production and producibility (source: "Libro Bianco: Isole Minori", 2019).

7.2 Territorial energy matrix

The case study is the Metropolitan City of Turin, identified as the optimal scale for implementing an energy metaplan, and a comparison of the 11 **homogeneous zones** identified by the metropolitan city. These zones are used to implement the city's strategies in an organized manner. A competent commission was formed to create these zones, taking into account each area's historical, territorial, social, and economic identity. Additionally, other parameters such as the organization of public services were considered, while paying attention to the geographical, historical, social, and economic characteristics of the territories. The demographic size and the number of municipalities within each zone vary significantly based on the territory's characteristics.

Since these territorial homogeneous zones were created to group together areas with similar characteristics, they are an optimal way to define **local development strategies**. The zones were chosen as the territorial reference dimension to facilitate the implementation of specific policies based on the characteristics of each area. The following information allows us to describe some of the primary spatial characteristics of the area under analysis.

Environmental and climatic morphological framework

The territory of the metropolitan city can be divided into three belts (Figure 18a) of which the prevailing and outermost is the alpine belt (23%). Within it is the hilly zone (43%), which includes the flat zone (34%). Piedmont is rich in waterways

such as rivers and streams, all of which are tributaries of the Po River that originates at the foot of Monviso. It is also characterized by several mountain ranges: the Alps and the Apennines, which occupy the region to the west and north. The region is characterized by a temperate climate with a continental character. Moving toward the Alps, it becomes progressively colder as it rises in altitude. In fact, Piedmont, as a region in the north of Italy, has a temperate climate. The lowland areas are characterized by cold, wet winters. Hot and sultry summers, on the other hand, with local chances of thunderstorms. Precipitation is abundant mainly in spring and autumn, and in summer in the higher alpine and interior areas: annual amounts are often considerable on the mountain and foothill slopes of the northern part of the region, scarce on the plains south of the Po, particularly in the Alessandria area. According to the provisions of Presidential Decree No. 412 of August 26, 1993, and on the basis of climate data from weather stations in the territory, it can be seen that there is a clear division between the lowland municipalities that fall within climate zone E, in particular 64% fall within sub-class E3, while the mountainous municipalities fall within class F (22% of municipalities), as shown in Figure 18b. The climate classification of Italian municipalities established by Presidential Decree No. 412, regulates the operation and operation of thermal systems in buildings with the aim of containing energy consumption. This classification is a useful degree-day classification of the Italian territory for energy planning purposes.

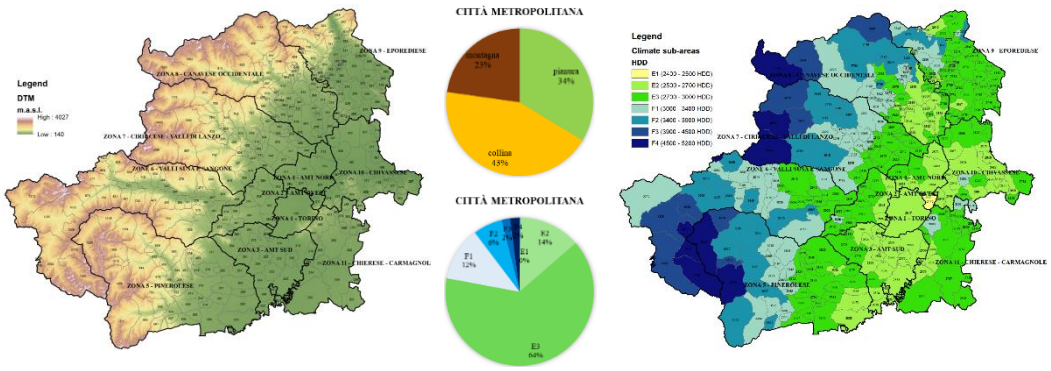


Figure 18: Altimetric zone, meter on the seal level, and Municipality percentage for altimetric zone (a) and Climatic zone, heating degree days (HDD), and municipality percentage for climatic zone (b).

There are a number of renewable resources in the area, some of which are already exploited and some of which have potential for energy production; as shown in Figures, a plurality of environmental and climatic characteristics emerge that affect the thermal and electrical energy consumption of different end users.

Socioeconomic characteristics of the population affecting the energy variable

The flat areas, especially those around Turin, tend to be the most densely populated. Nearly 80% of Piedmont municipalities have populations under 2,500, and 90% have fewer than 7,000 residents. Figure 19 shows that most less populated municipalities are in hilly and mountainous regions. However, there has been a noticeable growth in the population of municipalities in the flat areas, especially those near Turin.

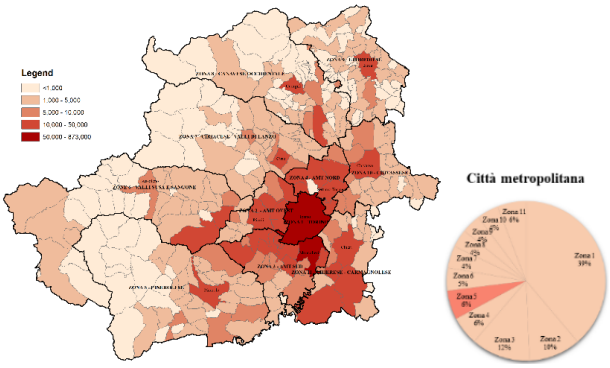


Figure 19: Number of inhabitants for census section and municipality.

For the analysis of the economic activities, Table 1 shows the number of employees in enterprises active in the municipality concerning each sector (Ateco code). The data for the metropolitan city of Turin shows data in line with the region's. Specifically, 30% of the employees are employed in manufacturing primarily, followed by 15.4% in wholesale and retail trade repair of motor vehicles and motorcycles. There are several reasons why many workers in manufacturing and, wholesale and retail trade repair of motor vehicles and motorcycles characterize Piedmont and the metropolitan city of Turin. Piedmont has a long manufacturing tradition dating back to the industrial era of the 19th century, with a historical presence of manufacturing firms in the automotive, aerospace, electronics, energy, and agribusiness sectors. The presence of critical infrastructure and the geographical location on the border with France and Switzerland has favored the development of wholesale and retail trade, particularly in the automotive and motorcycle sectors, with major brands such as Fiat and Alfa Romeo.

Table 1: Number of employees in active companies for economic activities sector.

Ateco 2007	CMTo	%	Piedmont	%
agriculture, forestry and fishing	590	0.1%	2341	0.2%

extraction of minerals from quarries and mines	332	0.0%	1476	0.1%
manufacturing activities	223,764	**30.0%**	415,161	**31.2%**
supply of electricity, gas, steam and air conditioning	5,904	0.8%	7,169	0.5%
water supply sewerage, waste management and sanitation activities	7,633	1.0%	12,910	1.0%
construction	59,006	7.9%	127,323	9.6%
wholesale and retail trade repair of motor vehicles and motorcycles	115,280	**15.4%**	238,023	**17.9%**
transportation and storage	35,127	4.7%	59,573	4.5%
accommodation and food service activities	37,068	5.0%	75,348	5.7%
information and communication services	41,142	5.5%	50,439	3.8%
financial and insurance activities	54,134	7.2%	68,617	5.2%
real estate activities	14,033	1.9%	24,914	1.9%
professional, scientific and technical activities	57,033	7.6%	93,877	7.1%
rental, travel agencies, business support services	49,810	6.7%	71,012	5.3%
education	3,544	0.5%	5,602	0.4%
health and social work	20,640	2.8%	34,997	2.6%
arts, sports, entertainment and recreation activities	4,696	0.6%	9,087	0.7%
other service activities	17,238	2.3%	33,131	2.5%
Total	746,974	100.0%	1,331,000	100.0%

Characteristics of the built-up area affecting the energy variable

The following section shows the main characteristics of the built-up area by comparing 11 homogeneous zones and the regional average data.

Figure 20a returns information on the prevailing era of construction of residential buildings by municipality, most of which indicates that the buildings were built before the 1970s. However, small rural municipalities have a large share of the built-up area constructed before 1919. Figure 20b shows the maintenance status of residential buildings: most buildings are in good or excellent condition. Other valuable characteristics to describe the settlement stock are the number of residential or other-use buildings, occupied or unoccupied housing units, and households by housing title. All information's available from Istat.

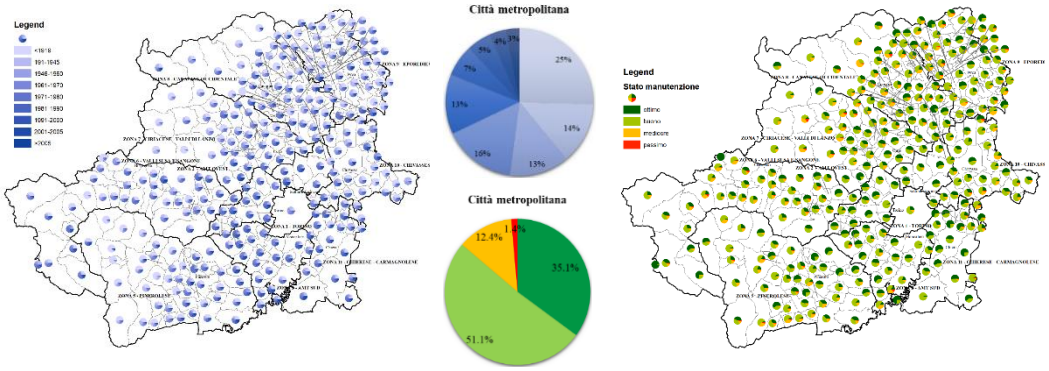


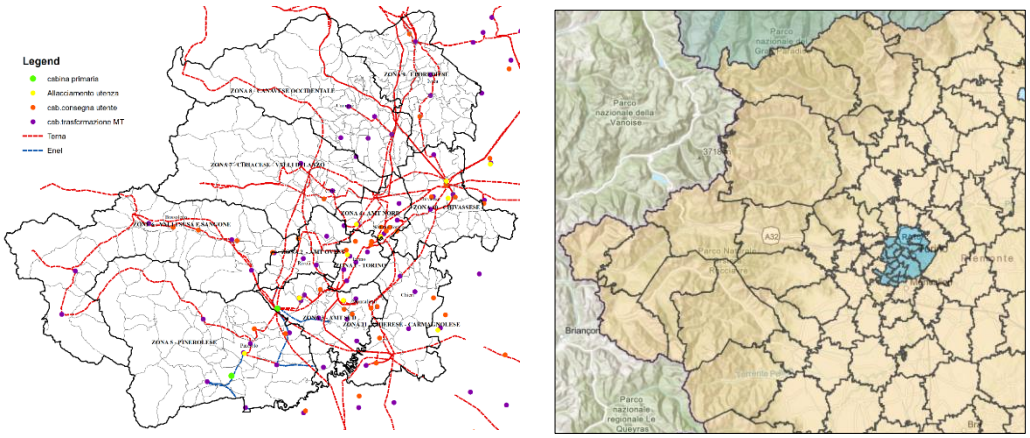
Figure 20: Epoch of building construction by municipality (a) and Maintenance status of residential buildings by municipality (b).

7.4 Energy analysis at territorial scale

Point and network infrastructure

This section is devoted to analyzing the existing electricity grid and the location of transformer substations between medium-low voltage (MV/LV) and high voltage (HV). The assessment of the power grid is crucial to make the renewable energy produced locally exploitable; in particular, the presence of a widespread and capillary power grid throughout the territory would make it possible to cover the electricity needs even in the presence of RES plants distributed throughout the territory.

The regional technical map displays the electricity grid and highlights the "Network of Subservices" nodes in Figure 21a. In October 2023, GSE released a map of the high voltage territories in Figure 21b, which legally defines the supra-municipal region capable of forming an Energy Community.



(a) (b)

Figure 21: Electricity grid organization (a) electricity grid and nodes; (b) High Voltage territories.

Specifically, an analysis regarding the type of fuel used, as shown in Figure 22b, the primary energy carrier turns out to be natural gas (74%), followed by solid fuel (10%), diesel (5%), LPG (3%), electricity (2%), and other fuel (6%). Therefore, as also pointed out at the national scale, the territory is highly dependent on fossil fuels, especially gas and methane, so it is necessary to aim for electrification of final energy consumption. Figure 22a shows the percentages of centralized systems for

the exclusive use of the dwelling, autonomous systems for the exclusive use of the dwelling, fixed individual appliances (chimney, stove, radiator, heat pumps, etc.) that heat the entire dwelling, or most of it, or that heat some parts of the dwelling.

Regarding the types of heating systems, as shown in Figure 22a, out of the total number of systems present, the most represented type is the stand-alone system type (42%), which, when considered with single systems, reaches 12%. In comparison, centralized systems make up 46%. Most single systems are in municipalities in mountainous areas.

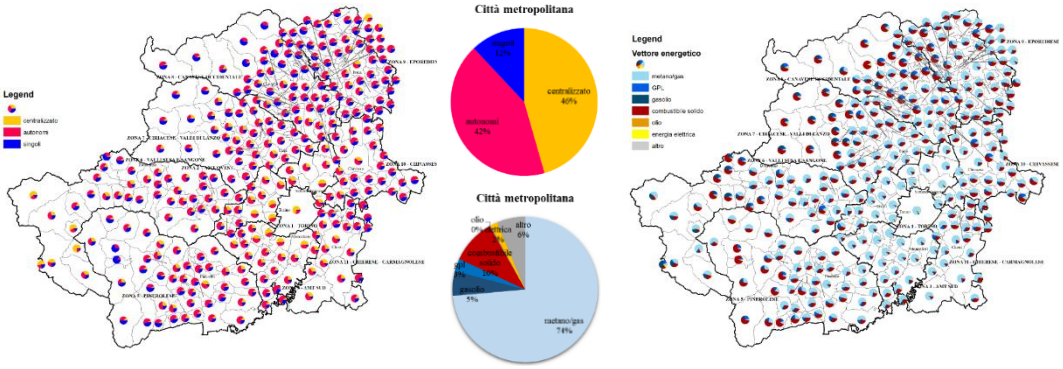


Figure 22: Type of heating system (a), and Type of fuel used (b).

Source of energy data

The energy data comes from various online databases, listed in Table 2. The GIS-based methodology allows the different databases to be merged at different scales, thus taking advantage of all available information even with different accuracy. In Table 2, the databases are by the type of information on buildings, population, climate, and energy data of consumption, production, and potential production.

Table 2: Territorial data source.

Tipology	Input data	Note	Source
Buildings, population, weather, territorial characteristics			
Built environment	CTR		Geoportale Piemonte
	DEM/DSM/DTM		ISPRA 20m
			INGV 10 m
	Land use		Mosaicatura
Socioeconomic characteristics	Census of buildings and population	For census section	ISTAT 2011
Weather characteristics	Weather data (T, UR, wind, solar irradiation, DD)		Arpa Piemonte
			PVGIS
			UNI 10349-1,2,3:2016
Energy consumption			

Energy consumption for the region	Regional energy consumption per tipology		Rapporto ENEA
Energy production			
Geographical and energy data	ATLAIMPIANTI portal and Rapporto Statistico GSE	Power and hours of use of existing plants (type, source, size, location)	Rapporto Statistico GSE (ore di utilizzazione) Atlaimpianti (impianti FER)
Energy producibility from			
Renewable Energy Sources	Solar irradiation	Calculating energy producibility (year-month-hour)	GIS-Area solar radiation Meteonorm & PVGIS website (JRC)
	Biomass		SIFOR
	Waste		ISPRA
	Wind		Atlante Eolico
	Hydroelectric		Geoportale Piemonte
Constraints on the extraction of RES resources/installation of RES plants	Environmental protection	Evaluation of actual producibility	DGR Piemonte PPTR Piemonte PPR Piemonte Geoportale Piemonte
	Landscape protection		
	Hydrogeological risk		
	Soil protection		

7.4.1 Energy consumption

The energy consumption analysis was carried out using data provided by energy distributors for various municipalities in Piedmont, covering 2017. The data was processed and geo-referenced to create a single map representing electricity consumption (Figure 23). The figures reflect the total electricity consumption derived from domestic, industrial, agriculture, tertiary, and commercial sectors. Figure 23, which shows the distribution of total electricity consumption, is similar to Figure 19, which displays the total resident population. The municipalities with the highest population, such as Turin and the surrounding areas, also take the lead regarding energy consumption.

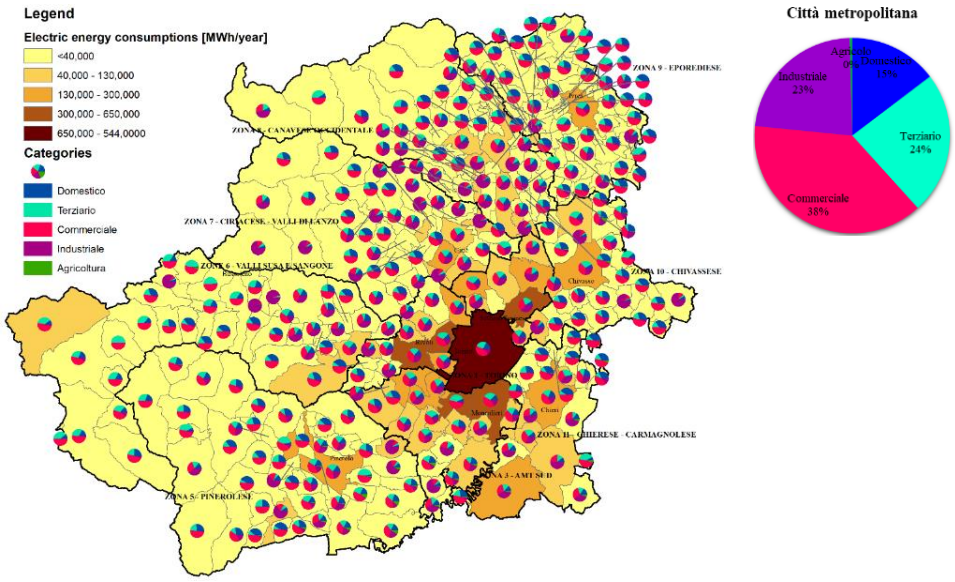


Figure 23: Annual total and sectoral electricity consumption by municipality.

7.4.2 Energy production from renewable sources

Data on energy production from RES were retrieved by consulting the Atlaimpianti online geographic portal of the Gestore dei Servizi Energetici (GSE). The portal considers thermal and electric power generation plants registered by the GSE as of February 2023. Table 3 represent the nominal installed capacity [kW] and annual electricity production [MWh/year] from each renewable energy source. The annual electricity production was estimated as a function of the average theoretical hours of operation (from 2015 to 2019) for each type of plant considered (Figure 24). The pie charts show the current composition of the energy mix of the territory analyzed and the Metropolitan City. The breakdown of annual electricity production from RES by plant type is as follows: 55% is produced by hydro plants, 17% by photovoltaic plants, and the % by biogas, liquid biomass, and solid biomass by 18%.

Table 3: Electricity produced by RES (GSE, 2021).

RES	Nominal power (kW)	Hours of utilization	Annual electricity production [MWh/year]
Biogas	55,667	4,669	259,911
Liquid biomass	30,169	4,669	140,859
Solid biomass	24,278	4,669	113,354
Wind energy	200	1,835	367
Hydraulic	705,740	2,331	1,645,081
Waste energy	65,500	4,669	305,820
Solar	423,751	1,188	503,417

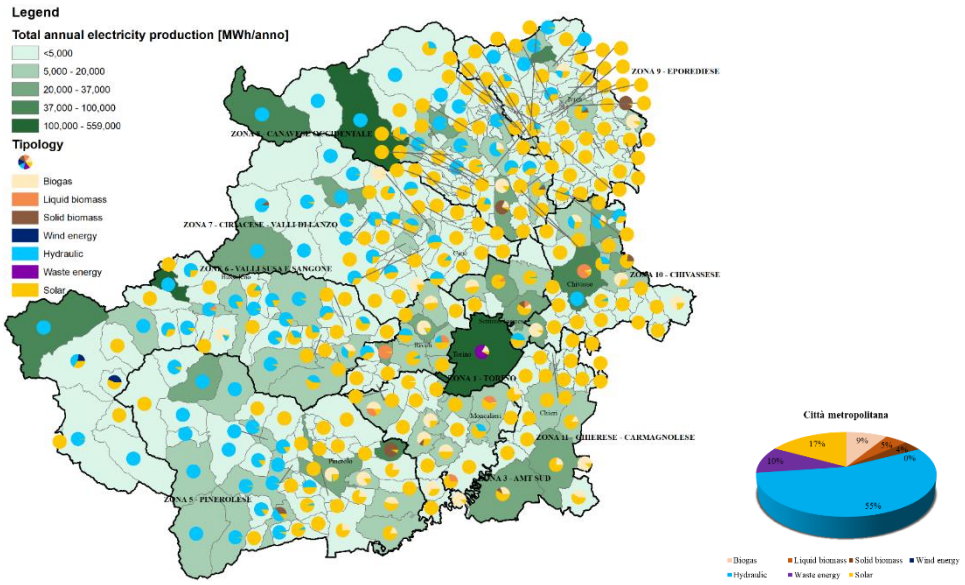


Figure 24: Total annual electricity production and by RES type by municipality.

It is possible to notice how the type of RES depends on the context analyzed, with a prevalence of hydro in mountainous areas and solar PV in flat areas. Turin is the municipality that produces the most energy and most from waste. Although electrical production is already substantial, this work aims to analyze the potential of the RES resources that are still available and can be exploited energetically in quantitative (increased production) and qualitative (improved energy mix) terms.

7.4.3 Theoretical production of energy from renewable sources

The area under analysis is diverse and rich in resources, but the current energy mix mainly focuses on exploiting hydraulic resources. In order to achieve a higher degree of energy independence, it is necessary to exploit locally available energy resources further. Creating a balanced energy mix helps to ensure the continuity of energy generation, obviating the variability and discontinuity of RES.

This section presents a **place-based** study of the utilization of renewable energy sources. In these analyses, the most accurate data and some reasonable approximations, described in detail, were assumed to arrive at indicative but scientifically validated values. This analysis will evaluate the use of solar, wind, and biomass energy, which, when considered together, could constitute an optimal energy mix to meet the energy demand of the area under analysis. Since the energy from renewable sources on a territory depends mainly on its characteristics, it is necessary to assess their availability and the theoretical and actual accessibility of

these resources, being influenced by technical, economic, or legislative constraints in relation to the specific territorial context. Technologies for energy production from renewable sources are expanding rapidly. It is, therefore, useful to have a **framework** of **analysis** at the broad scale of the territory, which helps to locate the most suitable areas for the withdrawal of the resource or the installation of new plants, but above all, about the presence on the territory of energy demand. The evaluation of renewable energies is restricted by online information, mainly from Geographic Information Systems and the computing machines available. Additionally, computational simplifications are necessary to make comprehensive assessment feasible.

Forest biomass

One solution to limit fossil fuel use and improve energy security from RES is to use local biomass for energy production. "Biomass" is defined by European Directive 2009/28/EC as the biodegradable fraction of residual products and wastes of biological origin from agriculture, forestry, and related industries, as well as the biodegradable part of municipal industrial waste. If well exploited, especially at the local scale, biomass can be considered one of the most promising renewable energy sources, as it could cover a considerable part of energy needs at the expense of fossil fuel use, resulting in reduced carbon dioxide emissions and favorable economic and social impacts. However, biomass is a limited resource, and its potential use is closely related to local availability. In addition, the combustion of agricultural and forestry biomass releases as much CO2 into the atmosphere as is absorbed by plants over their lifetimes and thus can be considered a carbon-neutral resource if local exploitation of the resource is compatible with the regrowth time of the plants themselves.

Calculation of electricity producible from forest biomass

1. Calculation of forest biomass availability. Based on the regional database (SIFOR) on land use, the forest area in the territory was estimated, distinguishing each forest category (Figure 25). The forested area covers about 242,269.71 ha of the area of the Metropolitan City, covering a percentage close to 35.5% of the entire land area.

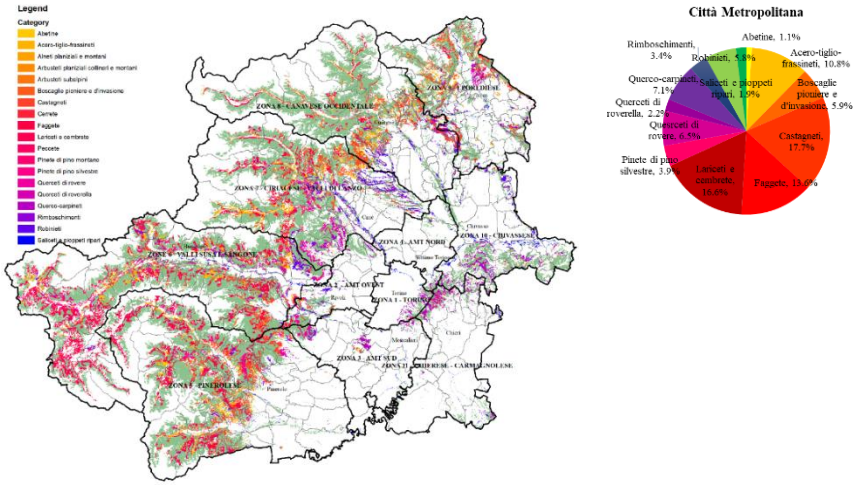


Figure 25: Available forest biomass by forest category and total forest biomass in green.

2. Calculation of accessible biomass areas. To be utilized, biomass must be accessible by means of transportation, which must necessarily be able to reach the areas involved in harvesting the resource. Therefore, slope slopes were associated with forest road information. For this case study, 34.6% of the available biomass was accessible (Regione Piemonte, 2007).

3. Calculation of electricity from forest biomass. Evaluation of the energy that a biomass power plant can produce takes into account the accessible area, the amount of biomass that can be exploited annually for energy production (taking into account the growth rate of tree species), the lower calorific value, and the power plant conversion efficiency (20%). This data was compiled in a provincial inventory in previous studies related to the territory of the Piedmont Region (Table 4). Figure 26 shows results for the annual electric energy [MWh/year] produced from forest biomass in each municipality, part of the analyzed territory. The availability of the resource is mainly in mountainous areas.

Table 4: Gross annual specific productivity (p) = [t/ha] and Lower Calorific Value of dry matter PCI = [kWh/kg], by crop type considered.

COD	Category	Area (ha)	Prevailing mass mc/year	Volumic mass Kg/mc^2	Available biomass (t)	Available biomass (t/ha)	PCI (kWh/Kg3)	Energy (kWh/year)
AF	Acero/tiglio frassineti	19648	10877	650	7070,05	0,36	4,1	1,48
AN	Alineti planiziali e montani	2081	4670,13	620	2895,48	1,39	4,1	5,7

AS	Arbusteti planiziali collinari e montani	938	34,13	525	17,92	0,02	4,1	0,08
OV	Arbusteti subalpini	839	5,2	500	2,6	0	4,1	0,01
BS	Boscaglie pioniere e d'invasione	11734	3303,93	500	1651,97	0,14	4	0,56
CA	Castagneti	68864	412305,46	540	222644,95	3,23	4	12,93
CE	Cerrete	916	1443,66	900	1299,29	1,42	4	5,67
FA	Faggete	17097	26409,33	730	19278,81	1,13	4	4,51
LC	Lacereti e cembrete	9824	7437,53	650	4834,39	0,49	4,3	2,12
OC	Olmo Castrieto	2239	4365,13	550	2400,82	1,07	4,1	4,4
PE	Peccete	901	1517,86	450	683,04	0,76	4,5	3,41
PM	Pinete di Pino Marittimo	216,15	206,06	450	92,73	0,43	4,4	1,89
PN	Pinete di pino montano	158,85	11.53	560	6,46	0,04	4,4	0,18
PS	Pinete di pino silvestre	2638,04	8676.73	540	4685,43	1,78	4,4	7,81
QV	Querceti di rovere	9690,56	8338,8	760	6413,49	0,66	4,2	2,78
QR	Querceti di roverella	13473,01	10633,2	760	8081,23	0,6	4,2	2,52
QC	Querco carpineto	11542,08	9281,4	800	7425,12	0,64	4,2	2,7
RI	Rimboschimenti	4164,78	16886,66	500	8443,33	2,03	4	8,11
RB	Robinieti	46416	59785.73	760	45437,15	0,98	4,5	4,41
SP	Saliceti e pioppeti ripari	3618	8260.53	650	5369,34	1,48	4	5,94

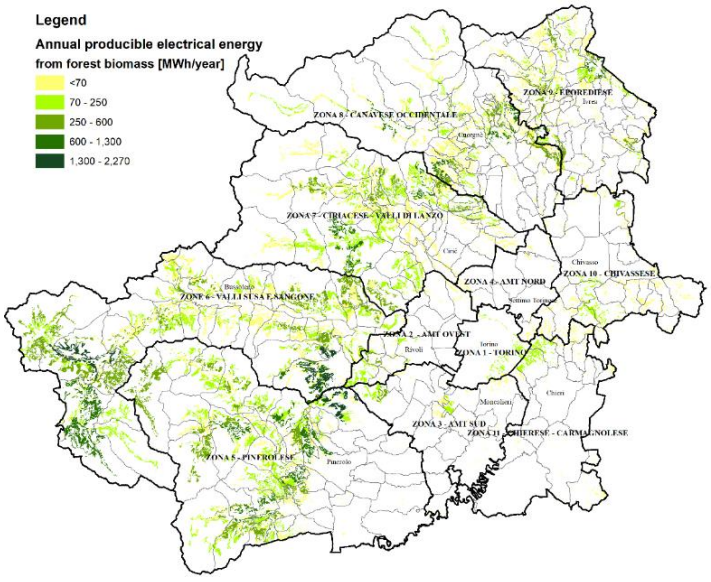


Figure 26: Annual electricity from forest biomass.

Agricultural biomass

The agricultural sector assumes an essential role in the renewable energy production sector since by conferring agricultural production waste as RES resources; there is no need to balance between harvesting and relocation of tree species, as in the case of forest biomass. In addition, the possibility of building new biomass cogeneration plants can offer new job opportunities throughout the entire energy process, from material harvesting to combustion to distribution, helping to create new jobs, particularly in a sector often subject to uncertain conditions such as agriculture.

Biomass of agricultural origin consists of various materials for energy purposes: crop residues, products of dedicated crops, woody residues from pruning, and waste from the agribusiness industry.

- **Crop residues**: waste from natural processes. Not all residues from this sector are energetically usable for energy reasons and because they are sometimes difficult and expensive to collect. For this reason, cereal straw, vine shoots, wood, and olive tree pruning branches are attractive. Production is simple and inexpensive for this type of biomass because it does not involve particular operational complications.
- **Pruning residues**: Pruning from vineyards and orchards produces large amounts of waste, the disposal of which is often a problem for farmers; otherwise, the waste can be valorized through delivery to biomass plants.
- **Waste** from agribusiness industries: by-products of food processes to produce dried fruits (shells and stones) and wine (pomace).

Calculation of electricity from agricultural biomass

The calculation of biomass originating from agricultural waste is similar to that for forest biomass. Following the evaluation of the area used, it is necessary to correct this result by multiplying it by the "unit yield" value and the "useful fraction" factor; the latter makes it possible to take into account the fact that not all biomass can be used for energy purposes since part of the waste is also used for other purposes.

1. Calculation of agricultural biomass availability. Based on the regional database (Land Use Classification, 2010) on land use, the agricultural crop category estimated the available agricultural area (Figure 27). The agricultural area covers

about 4.512 ha of the Metropolitan City's land area, covering 0.7% of the entire land area.

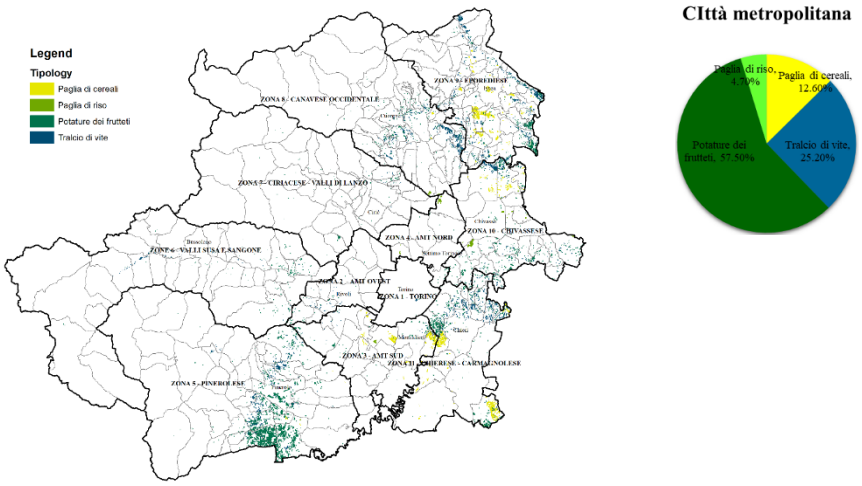


Figure 27: Available agricultural biomass by crop type.

2. Calculation of electricity from agricultural biomass. Evaluation of the energy that a biomass power plant can produce takes into account the accessible area, the amount of biomass that can be exploited annually for energy production (taking into account the growth rate of tree species), the lower calorific value, and the plant conversion efficiency (20%). This data was compiled in regional inventories (Table 5) in previous studies (Carlucci et al., 2015; Ente Nazionale Risi). Figure 28 shows the results of annual electric energy [MWh/year] that can be produced from agricultural biomass in each municipality that is part of the analyzed territory. Compared to the other available crops, with yields and yields in the average range, orchards possess a good applicable fraction and a far lower heating value. Creating an agro-energy supply chain on a supra-municipal scale could generate energy and economic benefits for the entire community, starting with the entrepreneurship already active in the area and facilitating the systemization of the other entities present through shared strategic spatial planning.

Table 5: Annual yield [t/ha], useful fraction [%] and PCI [kWh/kg] by crop type considered.

Types	Surrender [t/ha]	Useful fraction	Lower Calorific Value [kWh/kg]
Rice straw	2.87	60%	2.36
Rice husk	6.54	12%	4
Cereal straw	2.18	40%	2.36

Vine branch	1.45	30%	2.2
Marc and stalks	7.05	8%	2.2
Poteture of orchards	2.2	90%	3.4
Poplars	12	15%	2.2
Unsorted arboriculture	17.6	50%	2.2

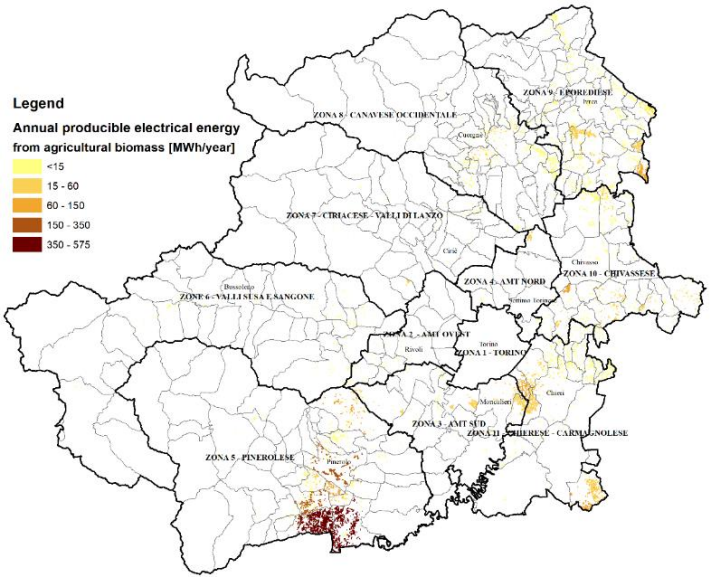


Figure 28: Annual electrical energy from agricultural biomass.

Biogas

Biogas is a mixture of gases, mainly methane and carbon dioxide, produced by the anaerobic fermentation of organic residues. Anaerobic digestion involves the breakdown of organic matter without oxygen by special bacteria. The fermentation process is thanks to special digesters in which the main operating parameters can be controlled, thus creating the best conditions for the bacterial flora. Various types of organic substances can be used for digester feeding. Due to the low supply cost, animal manure is a typical example of a widely used by-product in biogas production. In addition, the use of manure can significantly reduce pollution, particularly in areas where there are many intensive livestock farms. In Italy, about 7% of the renewable energy produced comes from biogas; Piedmont (12.6%) is the fourth largest region in terms of production.

Calculation of electricity producible from biogas

In order to calculate the biogas plant's nominal power output, it is necessary to estimate the quantities of substrates, **dry matter**, and **volatile matter** available.

Then, thanks to the specific biogas production coefficient, the amount of biogas produced is determined, and through the calorific value, the gross energy contained within it is determined. Then, the amounts of electrical and thermal energy produced are determined thanks to the engine's efficiency.

1. Calculation of head availability and manure produced. The livestock production orientation and the number of cattle present per municipality come from the 2010 Census of Agriculture. In this analysis, cattle are considered the most relevant in the area considered for the production orientation of meat (considered housed on straw bedding and producing manure) and dairy (considered housed without bedding and producing slurry). In order to calculate the manure produced by each cattle, data provided by an expert in the field who works were used (Prato, F., 2022). Given these considerations, on a dairy farm, a dairy cow produces an average of 80 kg/head/day of slurry. On beef farms, an average amount of about 14 kg/head/day of manure was considered (average between the amounts produced by closed-cycle and open-cycle farms).

Dry matter is the solid fraction of total matter, while volatile matter is the fraction of dry matter consisting of organic components. The volatile fraction of the total substance is that which, with the effect of the microorganisms in the digester, gives rise to biogas. In the calculations, the following percentages of dry matter (expressed as % of total matter) and volatile matter (% of dry matter) were considered (Table 6).

Table 6: Dry matter and volatile fractions of livestock manure (source: Consorzio Monviso Agroenergia).

Substance type	**Slurry**	**Manure**
Dry substance (ST)	8.5%	23%
Volatile substance (SV)	80.9%	80.2%

2. Calculation of electricity from biogas. After determining the quantities of available dry and volatile matter, the biogas generated can be calculated per unit mass of volatile solids. The specific production coefficient, empirically determined for each substrate, can be used to calculate the amount of biogas produced. This coefficient is in cubic meters (under standard conditions) per kilogram of volatile matter. In this project, a value (equal for slurry and manure) of 380 [$Nm3/tSV$].

The mixture is composed mainly of methane (around 55% by volume) and carbon dioxide (around 40%), along with traces of other substances like hydrogen sulfide and ammonia (Calbry-Muzyka et al., 2022). Therefore, the PCI of biogas is

approximately equal to 5.46 kWh/Nm3. Data from the technical data sheet (Jenbacher J316 with 1,119 kW thermal output) as a reference to evaluate the power generation by indicating the average electrical efficiency of the engine as 37.5 %.

The operating period of a biogas plant is about 8,500 hours year (Gandiglio et al., 2016). Figure 29 shows that production from biogas is higher in lowland municipalities with little urbanization due to the high concentration of livestock and farms.

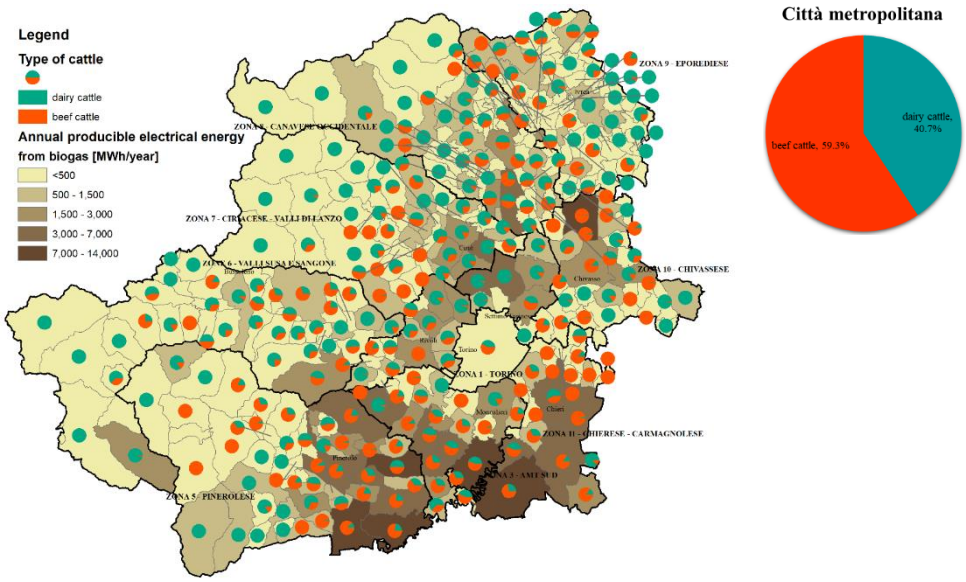


Figure 29: Annual producible biogas energy.

Energy from waste

The European Directive 2008/98/EC defines *waste* as any substance or object the producer or holder discards or intends to discard. In order to safeguard the environment and human health, the directive introduced a clear hierarchy of the different waste management methods, which are as follows: 1) reduction, 2) preparation for reuse, 3) recycling, 4) another recovery (e.g., energy recovery), and 5) disposal. To date, energy recovery from waste combustion takes place through waste-to-energy plants, which have brought technological innovation in the energy utilization of waste, surpassing incineration alone. Within waste-to-energy plants, it is possible to produce thermal and electrical energy (cogeneration system) through the combustion process of municipal solid waste (MSW).

The results obtained from this assessment outline the situation in which the area under analysis finds itself today. It also allows us to analyze the economic implications of this type of recovery activity.

Calculation of electricity producible from waste

1. Calculation of the amount of waste produced in the area. For the quantification of municipal waste, reference was made to the indicator "Total municipal waste production per municipality," covering 2021 and expressed in tons [t]. These data come from the ISPRA Waste Observatory.

2. Calculation of the waste to produce energy. The quantities of waste produced by distinguishing the component category. Table 7 shows the average characteristics for each component of municipal solid waste produced in Italy: the usable fraction (content), the degree of renewability, and the renewable fraction expressed as a percentage of the total waste produced annually, and the Lower Calorific Value (PCI) (Erichsen & Hauschild, 2000; "Urban Waste Report of ISPRA).

Table 7: Average characteristics of Municipal Solid Waste generated in Italy estimated by ISPRA.

Component	Content (%)	Renewability (%)	Renewable fraction (%)	PCI (MJ/Kg)
Organic	34,4	100	34,4	6,6
Paper	22,8	100	22,8	15,2
Plastic	11,6	0	0	40,7
Metals	4,3	0	0	-
Glass	7,6	0	0	-
Wood	3,8	100	3,8	16,7
WEEE	2,4	0	0	2,4
Textiles	5,1	50	2,5	13,5
Inerts	2,4	0	0	6
Other	5,5	10	0,5	6

3. Calculation of producible energy. In order to obtain the annual producible electric energy for each municipality, the thermal energy obtained from the combustion of the total waste produced was multiplied by the plant efficiency, assuming it to be 20%. Figure 30 shows the annual electrical energy [MWh/year] results from the treatment of municipal solid waste in each municipality that is part of the analyzed territory. The energy through the valorization of municipal waste is higher in the most populated municipalities (note the municipality of Turin); this result depends solely on the calculation method that multiplies the average annual production of waste per capita by the number of residents in the municipality. Among the assessments related to the exploitation of waste resources, the most

relevant and crucial issue is the choice of the site of the waste-to-energy plant. In addition to taking into account the regulatory constraints about the areas that can be considered suitable and assessing the logistic-economic optimization of waste collection and delivery to the plant, the process of deciding the location of the waste-to-energy plant must be as inclusive and participatory as possible from the community and local government, in order to ensure the understanding and sustainability of the project itself.

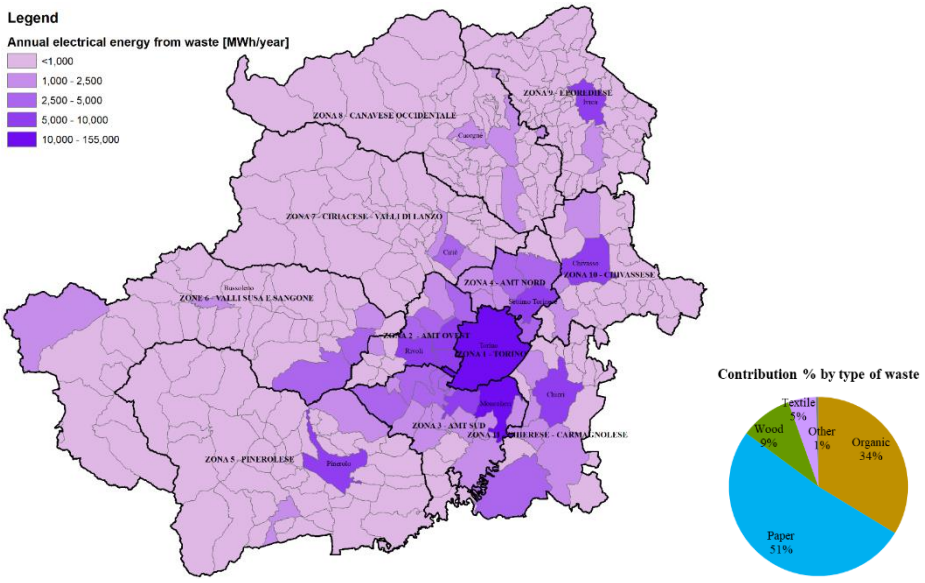


Figure 30: Annual electrical energy from waste.

Wind energy

A wind engine can convert the kinetic energy of air into mechanical energy that drives mills, pumps, or electric generators. Unlike water, air flows cannot be concentrated or stored and change direction and speed frequently. The capture of wind kinetic energy occurs through the surface of wind blades.

Calculation of electricity from wind power:

Even though the area needs to be better suited for the exploitation of wind speed due to the proximity of the Alps for renewable energy production. The analysis of wind source utilization is according to the following points:

1. Calculation of the amount of wind on the territory. Wind speed data comes from the Italian Wind Atlas and the meteorological institute ECMWF reading

service. The elevation of 25 m above sea level and the mean annual wind speed according to a 1 km x 1 km mesh. Figure 31 displays the outcomes of the annual electricity production [MWh/year] generated at a height of 25 meters in every municipality within the analyzed territory, based on a grid of 1 km x 1 km. The height of 25 meters is chosen based on the type and height of the blades for small-scale plants. By the regional guidelines mentioned below, small plants were preferred in this study to minimize the visual impact on the landscape.

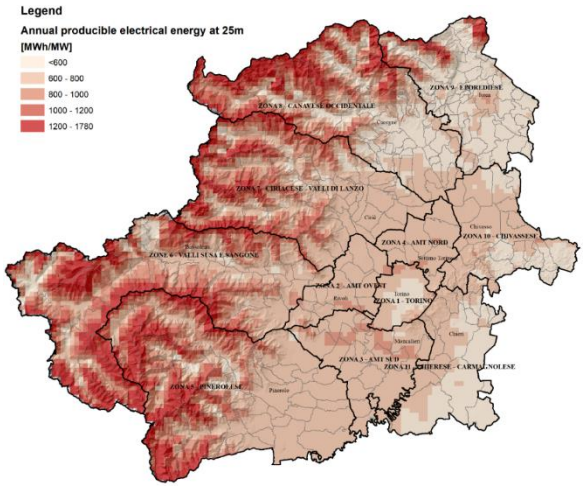


Figure 31: Annual producible electrical energy at 25 meters on the ground.

2. Calculation of energy productivity. In order to identify suitable areas for the installation of wind power plants, it is necessary to consider the spaces appropriate to the size of the various wind turbines. The assessment regarding the location of wind power plants and unsuitable areas considers the assessment constraints defined by the Implementation Regulations of the Decree of the Ministry of Economic Development of September 10, 2010, and the Regional Territorial Landscape Plan (PPR) of the Piedmont region.

There is a need to frame wind power development policies in a broader strategy to articulate and extend its potential to medium and small scale to articulate better local renewable energy production aimed at self-consumption. As anticipated, this work considers small wind turbine installations but excludes small wind turbines in integration with building roofs. Therefore, the potential energy productivity considers the installation of wind turbines with rotor hub height at 25 meters above ground level, with a rated power of 50 kW and a rotor diameter of 19 meters (thus considering a typical installation with characteristics according to the datasheet). The chosen technology is conventionally used in wind farm implementations with

an optimal average turbine spacing of 7 times the rotor diameter (Meyers & Meneveau, 2012), so each plant occupies an area of about 14,000 m2. In this work, a conversion efficiency of 40% (Energy Efficiency and Renewable Energy, 2018). The results related to the evaluation of annually producible electricity shown in Figure 32 refer only to the areas suitable for the installation of small wind power plants (micro-wind 20kW<x<60kW) on the territory of the Metropolitan City, in compliance with the constraints defined by the legislation mentioned in Chapter 11.2.2. In addition, it is necessary to consider that, on average, a wind power plant starts producing energy efficiently at wind speeds of at least 4-5 meters per second (about 14-18 kilometers per hour). Therefore, only those areas with values above four m/s wind speed were retained.

In this case study, the wind resource is the least exploitable among the renewable sources analyzed in the area under study. This circumstance is because of the conformation of the territory under analysis, which the Alps surrounds, has low wind speeds, and has many constraints that limit resource exploitation.

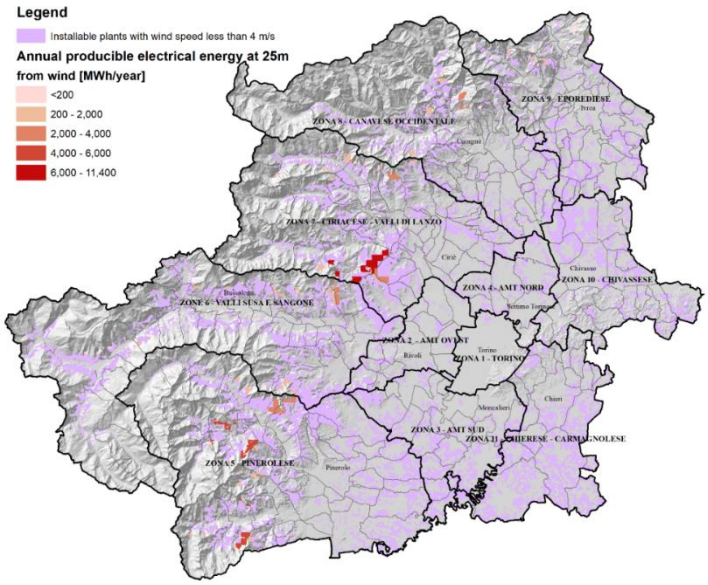


Figure 32: Annual electrical energy at 25 meters in areas suitable for the installation of wind power plants.

Solar energy

This section presents an assessment of the energy that can be produced by photovoltaic technology available on the market, assuming its integrated application on the roofs of buildings, according to current regulatory dictates. The

Ministry of Environmental and Cultural Heritage (MIBAC), through Presidential Decree 31/2017, has defined simplified procedures to be applied throughout the country, which allow the installation of renewable energy systems. The solutions indicated allow the panels to be installed in integration with the roofs of existing or future buildings to limit their visual impact on the landscape.

Solar technology converts solar radiation into thermal and electrical energy using solar collectors and photovoltaic panels. For the latter, the conversion efficiency (ηmc), i.e., the ratio of incident solar energy to electrical energy produced, varies according to the technology of the system: monocrystalline silicon (ηmc =18%), polycrystalline silicon (ηmc =16%), and thin film (ηmc =8%).

Calculation of electricity from solar energy

This analysis selected a photovoltaic system with 15% conversion efficiency for integration with existing building roofs. The analysis considers the geo-morphological characteristics of the area, the solar encumbrances, the type of sky, and the territorial constraints in force about the areas suitable for the installation of the systems. This analysis is according to the following points:

1. Calculation of monthly solar radiation incidents on the territory. The digital terrain model (DTM) with an accuracy of 10 meters, available on the regional portal, was used to assess solar radiation incidents on building roofs. A Digital Surface Model (DSM) can provide a more accurate analysis by including the orientation and inclination of roof pitches, but it requires longer simulation times. The procedure was performed with the "Area solar radiation" tool of ArcGIS software, considering the main seasonal characteristics of the sun and sky: percentage of the diffuse solar component on the global (D/G) and transmissivity of the atmosphere (T). The values considered are shown in Table 8 and represent the average value calculated over the total municipalities in the area under analysis. As an example, Figure 33 shows the analysis result regarding the horizontal solar irradiance incident on the ground in January.

Table 8: Monthly average values of the ratio of diffuse radiation on global (D/G) and transmissivity (T).

Month	D/G	T
January	0.43	0.58
February	0.40	0.57
March	0.39	0.62
April	0.32	0.69
May	0.30	0.69
June	0.22	0.71
July	0.20	0.75
August	0.30	0.71
September	0.30	0.73
October	0.38	0.57
November	0.38	0.51
December	0.43	0.49

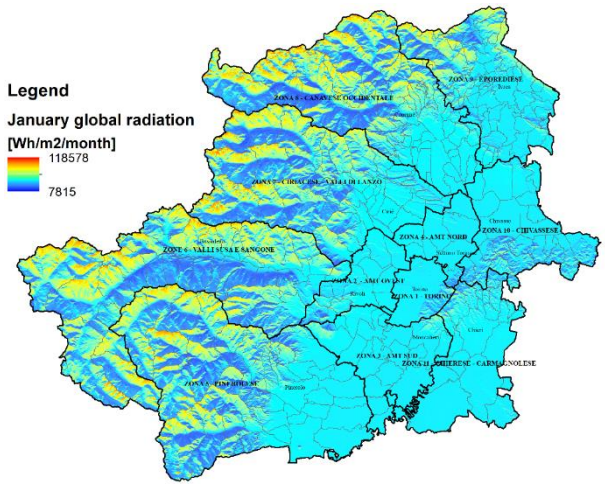


Figure 33: Horizontal solar irradiation [Wh/m^2] in the month of January.

2. Calculation of solar radiation on building roofs. The Regional Technical Map (CTR) is applicable to finding the buildings' location in the area of interest. This allowed us to measure the amount of solar radiation that the roofs of these buildings receive throughout the year and during different seasons. We only considered points that receive more than 1200 kWh/m2/year of cumulative annual solar irradiance. In this way, it was possible to determine the cumulative annual solar irradiance on each available roof, assuming 20% of the total surfaces suitable for installing photovoltaic panels. This methodology allows considering the type of building, the geometric and orientation characteristics of the roof, and the presence and area of objects and obstacles on the roofs, which limit to a partial use of the available surfaces.

3. Calculation of the electricity. Assuming the installation of photovoltaic panels with conversion efficiency under standard test conditions (η=15%) and the performance index of the entire system equal to PR=75% (Šúri, M. et al., 2007), it was then possible to calculate the energy that can be produced annually on each roof, according to the following relationship (Eq. 3):

$$E = PR \; x \; Hs \; x \; S \; x \; \eta \qquad (3)$$

Where E is the electricity produced per year [kWh/a], S is the PV panel area [m^2], and Hs is the annual cumulative solar radiation [kWh/m^2/a].

Figure 34 reports the amount of electricity that can be produced (E) from the total number of installable panels per census section, considering the optimal installation conditions on the available surfaces (20% roof area) and the performance of the chosen technology. On the one hand, photovoltaic technology ensures a spatially widespread and distributed electricity generation over the territory. However, at the same time, it requires an equally widespread and capillary infrastructure to feed the energy produced into the grid. As seen in Figure 34, photovoltaic systems make it possible to produce energy from RES even in urban centers, unlike other sources. In addition, the discontinuous nature of solar source presence, conditioned by daily cyclicality and climatic variability, should be considered.

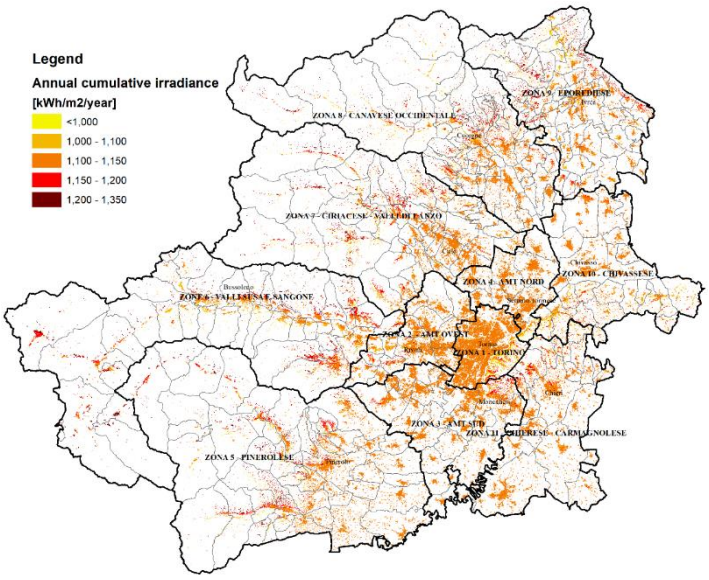


Figure 34: Annual cumulative irradiance on built-up area [kWh/m^{2}year].

Hydropower

Among the various types of existing hydropower systems, this paper has referred to the run-of-river and basin type of hydropower systems, which take advantage of the elevation difference between the water resource outflow elevation and the elevation of the turbines. Hydropower systems for electricity production base the transformation of gravitational potential energy into kinetic energy; this kinetic energy is then transformed into electricity in hydropower plants using an alternator coupled to a turbine.

Calculation of electricity from hydropower

Calculating the flow rate of the watercourse and the jump between two points from a higher to a lower elevation. The simplified procedure is as follows:

1. Calculation of the elevation of the intake and arrival points. To evaluate the slope of the terrain, use the digital terrain model at 10 meters. Calculating the height difference (sH) in meters and the stream's flow rate (Q) in cubic meters per second between two points on the slope. In the area under analysis, identify the afferent flow rate (Q) that does not consider any water usage, the height difference (H) between the intake and return points, and the length of the considered stretch.

2. Calculation of hydropower produced annually. In order to determine the electricity that can be produced annually by a hydroelectric plant, reference to the following formula (Eq. 4) where:

$$E = g \, x \, H \, x \, Q \, x \, \eta \qquad (4)$$

Where Q is the flow rate, H is the height difference, g is the acceleration of gravity (9.81 m/s2), and η is the conversion efficiency of a hydropower plant (80%) (Nazari-Heris, M., & Mohammadi-Ivatloo, B., 2017).

3. Calculation of potential energy producibility. The calculation does not consider the available hydropower resources, for which an investigation of water uses and any ecological or environmental constraints might limit the use of the resource. The results shown in Figure 35 indicate point calculations related to the points of stream restitution, the point where it is considered renewable energy production facilities will be located (in blue), and calculations of the potential from residual hydropower from the irrigation system given the theoretical powers and irrigated areas present in each agricultural consortium (in teal) (Bourcet, M. (2017).

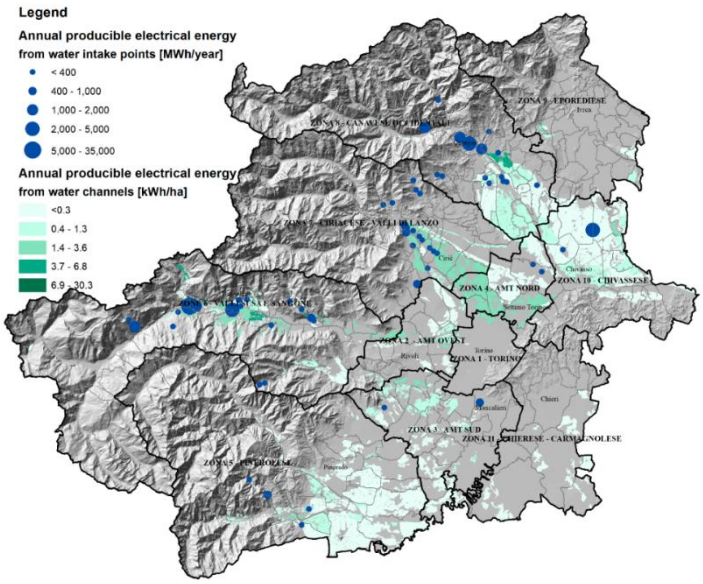
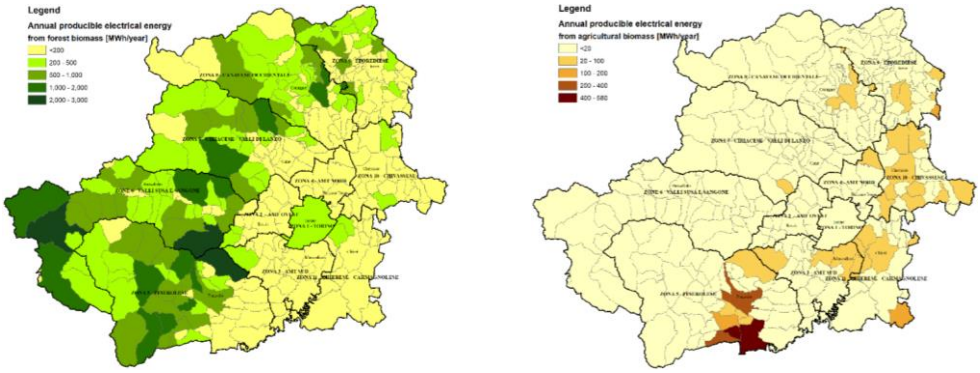


Figure 35: Annual hydropower energy from canals and river intake points.

RES producibility by the municipalities

This section briefly summarizes the results of the analysis of the potential producibility of the territory of the Metropolitan City of Turin, considering the different types of RES sources available. The producibility thus evaluated the **theoretical producibility (PPt)**, as it considers all present and available renewable resources, including those already exploited by existing RES plants. For each RES source, annual electrical producibility data were geo-referenced over the territory of each municipality considered. By looking at the results shown in Figure 36, it is possible to determine the energy vocation specific to each municipality in the area.



(a) (b)

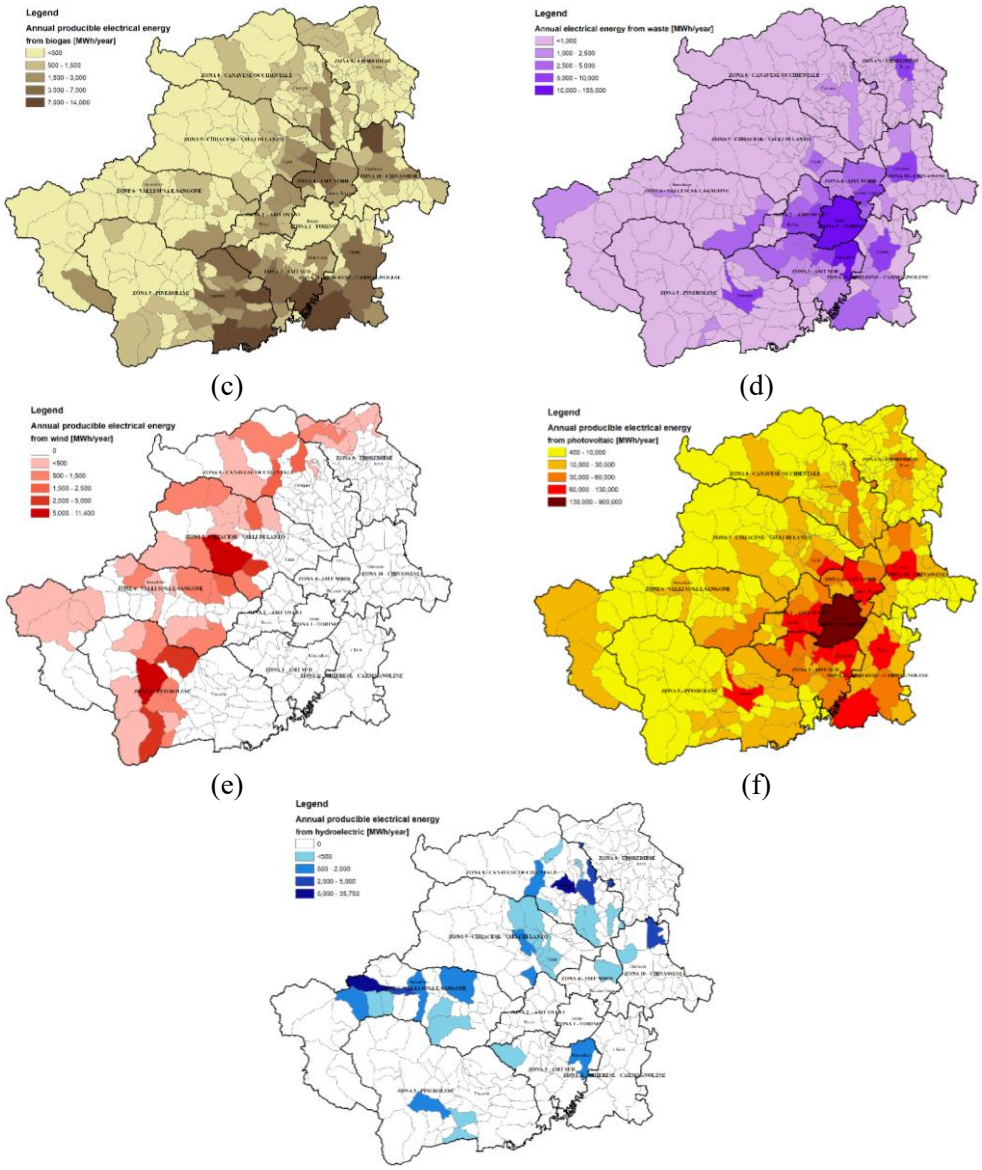


Figure 36: Theoretical annual electricity production from (a) forest biomass, (b) agricultural biomass, (c) biogas, (d) waste, (e) wind power plants, (f) solar photovoltaic, and (g) hydroelectric.

7.4.4 Energy balance

The presented energy model is designed to work at a large spatial scale. It aims to provide a more accurate assessment of single energy systems by simplifying handling extensive data. This model allows for point results based on information available at a larger scale, such as municipal, regional, or national levels.

The georeferenced information system can manage information from multiple sources by overlaying data and creating a single spatial database. This system makes it possible to visualize the spatial distribution of spatial characteristics, consumption, and producibility of different renewable sources. By overlaying this information, it is possible to compare municipal electricity consumption data with production and production from renewable energy sources. This assessment allows for comparing future scenarios, which can help identify the most effective energy policies and financial instruments to promote energy transition and sustainable land development.

Comparison of produced and producible energy

In order to support local stakeholders in identifying targeted local energy policies, the first assessment of the territorial energy balance compares the results for **existing renewable production (P)** and theoretical potential producibility (PPt). The goal is to determine the margin of increase in renewable energy production by source type at the municipal detail scale. In this way, it will be possible to highlight the territories suitable for exploiting RES resources or installing new plants to improve production and the local energy mix. First, it is good to distinguish between:

Theoretical producibility (PPt). The electrical energy from exploiting all the resources present for each type of RES source, including those already enhanced by existing RES plants, determines the existing amount of electricity produced (P).

Real producibility (PP). The remaining electrical energy is from untapped renewable sources without considering existing plants. It expresses the maximum achievable margin of increase in exploiting local RES resources. It is calculated, for each type of RES source, as the difference between theoretical producibility and existing production (Eq. 5):

$$PP = (PPt - P) \quad (5)$$

Maximum producibility (PPmax). The maximum producible electrical energy the territory can reach thanks to the exploitation of all available energy resources, both those exploited that contribute to the definition of existing renewable production (P) and those potentially still exploitable that contribute to the determination of real producibility (PP). For the calculation, the following relationship applies (Eq. 6):

$$PPmax = (P+PP) \qquad (6)$$

Municipal-scale results for existing production (P) and real producibility (PP) have been georeferenced and shown in Figures 25 and 37, respectively. In addition to the indication of annual electricity produced [MWh/year], the contribution of RES sources to total production/producibility. The pie charts in Figure 25 represent the current municipal energy mix. Figure 37, on the other hand, offers indications of municipalities where there is still **exploitable potential** for renewable energy production, providing indications of the distribution of this potential among different RES sources. Note how high-producing municipalities still have ample space to implement RES sources through energy mix diversification.

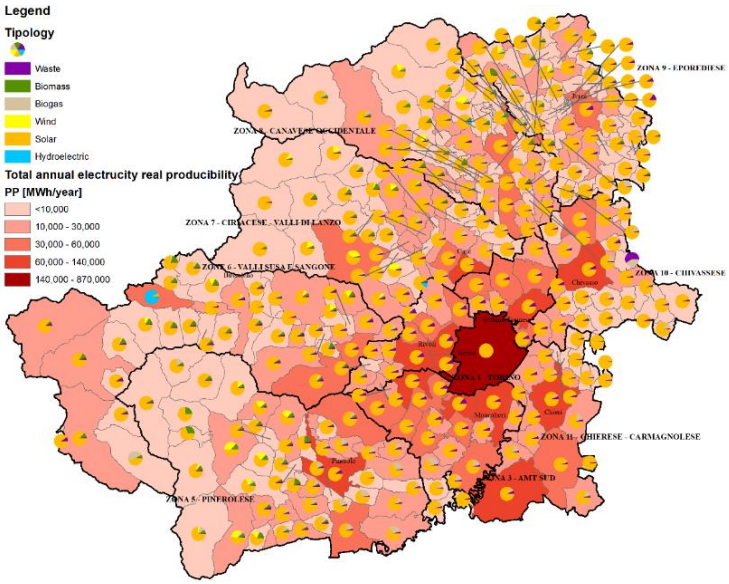


Figure 37: Real electricity producibility by municipality.

Annual energy independence index

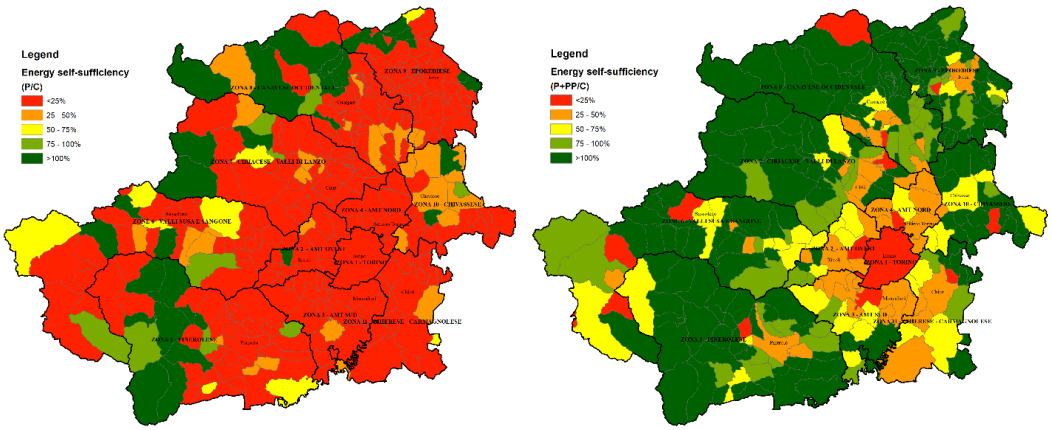
The goal toward which territorial energy planning is oriented is to achieve the highest level of energy independence. In order to assess the effectiveness of implementable energy policies, it is necessary to use specific indicators that facilitate the comparison of different conceivable scenarios. In this work, the annual energy independence index represents the territory's ability to meet total electricity demand with renewable electricity production. The index is the ratio of RES electricity production to electricity consumption, evaluated annually. In this way, reading the result is simplified:

- to an index < 1, corresponds to the failure of local RES production to cover the electricity demand and, consequently, the need to draw energy from the national grid.
- to an index >= 1, corresponds to the ability to fully cover the electricity demand and the possibility of selling the excess production on the national grid.

Energy independence assessed on an annual basis does not take into account the variable and discontinuous character peculiar to some of the RES sources considered (wind and solar first and foremost); therefore, an accurate estimate of the energy produced and instantaneously consumable or storable can only be determined by resorting to energy data at the hourly scale of detail.

First, the current energy scenario was described. In this scenario, the **energy independence index** is the ratio (**P/C**), where "P" is the total annual production from RES and "C" is the total annual consumption, considering all sectors. The result shown in Figure 38a indicates that in the current condition, the available RES production cannot cover the local electricity consumption annually due to substantial consumption and underutilized RES. As shown in Figure 38a, in the current condition, almost all municipalities are not energy independent (values < 1); of the remaining ones, all are energy independent due to high existing RES production and low energy consumption. Meanwhile, in the PPmax scenario, the municipalities that exceed 100% self-consumption are many and essentially correspond to those that have low energy consumption in Figure 38b. It is evident that in major cities, among them Turin, the share of self-consumption is low due to the high energy demand and the low availability of renewable sources.

Finally, analyzing the annual energy balance of the Metropolitan City (Figure 39), we observe that with a scenario in which all available resources are exploited, **52%** of the total demand. This coverage should lead us to think about **different solutions** such as improving the efficiency of plant technologies, reducing energy consumption and shrinking spatial constraints for the exploitation of RES, and especially finally, the use of nuclear energy to meet the essential (constant) consumption of energy needs and exploit RES for peak demand.



(a) (b)

Figure 38: Energy independence of (a) the BAU scenario of existing RES production and (b) the PPmax scenario of maximum production from RES by municipality.

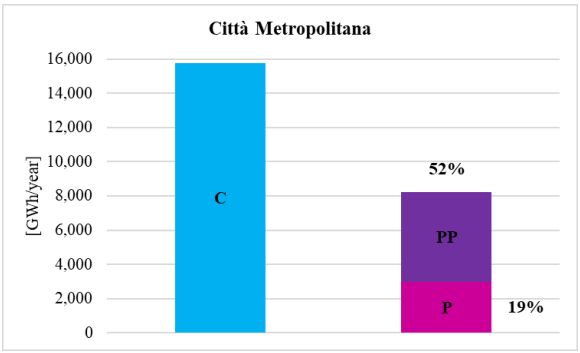


Figure 39: Energy balance of the territory of the Metropolitan City of Turin.

In addition to the spatial component, energy communities involve the **temporal component** (hourly energy exchange), as seen in the previous chapter. Therefore, to get an overview, methods are used to profile the production and consumption components, from annual to monthly data to hourly values. As we have seen, simplifications must be made to this end, as explained before.

These simplifications provide a monthly time-scale view of the data and see how, in general, energy demand decreases in summer months, mainly due to activity closures and favorable weather conditions—a period when production is higher, mainly due to higher availability of solar energy (Figure 40). Comparing maximum achievable production and energy consumption shows that production never exceeds consumption, even in summer.

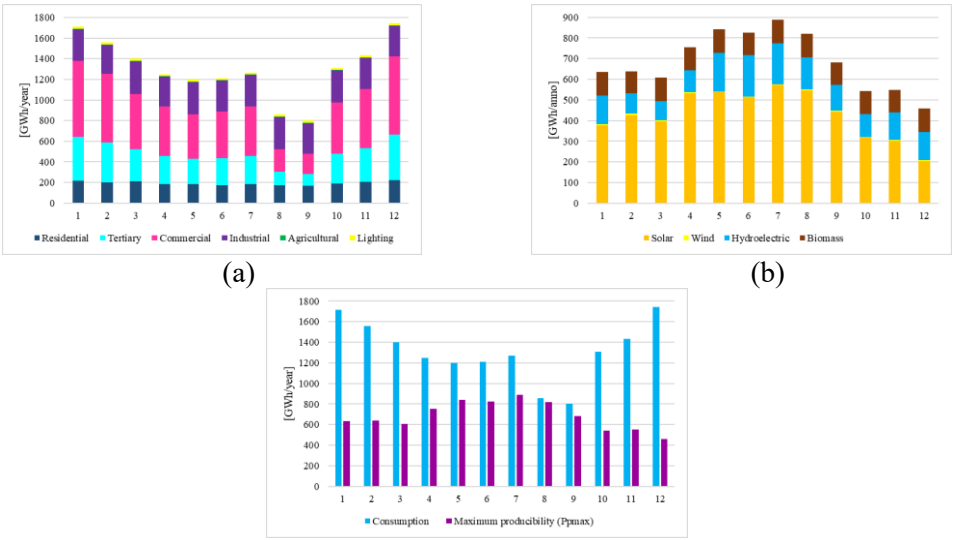


Figure 40: Monthly energy consumption and production: (a) consumption by sector (b) maximum producibility by FER (c) consumption and production comparison.

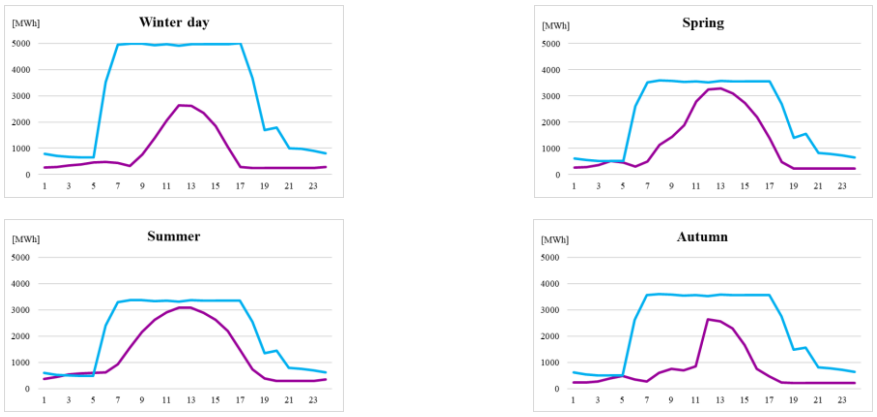


Figure 41: Hourly energy consumption (blue) and maximum producibility (violet) in four representative days.

In conclusion, the hourly energy profiles show the profiling of 4 typical days, representing the trend in the four seasons. The results in Figure 41 show a wider gap between production and consumption in autumn and winter that, in contrast, decreases in summer and spring, given the lower consumption and higher production from solar. From the analyses developed here, there is a need for an evaluation system that allows the **spatial** and **temporal** variables involved to be modified and flexibly. In Appendix A, a platform implemented based on the analyses carried out so far is proposed that is useful for improving the collimation of supply and demand.

Chapter 8 Good Practices

Good practices

This research chapter analyzes best practices and examines applications in the Emilia-Romagna region, focusing on two Italian city plans, Bologna and Modena, and the Danish case, which is centered on community energy.

In Italy, the link between energy planning and spatial government is guided by regional regulations (Chapter 4.2). The directions introduced at the regional level include:

- The Emilia-Romagna region thanks to the Regional Urban Planning Law 20/2000 (evaluation from an energy-environment perspective) and the Territorial Energy Planning Law 26/2004, which prescribes the conformity of plans with urban planning instruments and consistency with regional energy planning guidelines (a concept confirmed in the 2007 Regional Energy Plan).
- The Lombardy region thanks to Regional Law 26/2003 and 12/2005 the introduction of parameters and indicators of a building, urban planning and environmental character and requirements of energy value.
- The Marche region reference is the PEAR of 2005 (in absence of specific legislation), provides for responsible growth of the territory taking into account the energy aspect.
- Similarly to the Marches, Lazio, but with the peculiarity of the PTPG of the Provicia di Viterbo (provided for by the D.G.P. of Viterbo 311/2001), which provides plan strategies for the efficiency and security of energy supply, declined at the local scale according to territorial units of intervention.

Without considering the numerous short- and medium-term climate change adaptation plans developed and implemented separately from the urban plan, the most mature planning experiences move in the direction of transforming the **existing city**. The attention given by the legislator is still focused on the verification

of building energy parameters combined with incentive and disincentive measures; thus, a **limited sectoral approach** is configured (Dall'ò & Galante, 2009; De Ioris, 2014).

Moreover, the regional level is only the first step; moving down in scale, the energy aspect invests other issues. The plans at the municipal scale, continue to target the building sector through incentives to contribute to a significant improvement in the energy performance of building and technological systems. Bologna's plans (pioneering plan on the topic), Venice's PEC, and Monza's PGT focus on **standards** of a technological nature, while the ways in which to operate in the context of urban planning and design remain **unclear**. Indeed, achieving goals in the urban context requires **strategies** that overcome the limitations of local administrations (Verones & Zanon, 2013).

The integration of energy sustainability goals within spatial and urban planning tools, could not find in Italy, consolidated experiences at the vast area scale. Some experiences are those of the guidelines of the Province of Viterbo and the PTCP of Reggio Emilia. But it is with the PRODEM research that for the first time a **new methodological approach** has been outlined in the form of a meta-plan focusing on the energy variable at the vast area scale (ASUR, 2021).

In Italy, introducing new regional legislation and an initiative promoted by the European Community Conference of Mayors allowed for integrating the Urban Energy Plan. These developments were critical catalysts for addressing energy and planning issues (De Pascali & Bagaini, 2019; Alagna et al., 2021). Several best practices have emerged in **Emilia-Romagna** region, contributing to the evolution of sectoral planning in the Italian context. The process began with a cognitive framework and led to the inclusion of energy issues in the normal planning process, anticipating energy needs and creating harmony between the supply and demand system and local demand. This approach regulates local planning and action at all levels.

Following an analysis of Emilia's plans, the decision was made to focus on the plans of **Modena** and **Bologna**, which were considered the most relevant and innovative in this field (ASUR, 2021). The case studies of urban energy plans present three main characteristics: regional energy-specific legislation, multiple plan objectives (environment, settlement, energy), and the definition of hybrid intervention units.

In any given territory, gaining the support of the local community is essential to achieve a democratic and shared energy transition. Implementing a socially just energy transformation requires the active participation of communities by involving them in new renewable energy projects to achieve independence from the fossil fuel industry. In this context, Energy Communities offer a solution for energy security and access to clean energy, offering an opportunity to improve the integration of energy and spatial planning to address current urban challenges.

A model of local energy cooperation has been developed in **Denmark** since the 1970s and subsequently spread to other Nordic countries such as Netherlands, Sweden, United Kingdom, and Germany. The Danish government is among the first countries to have supported renewable energy through policies and financial arrangements. These national efforts have contributed to the growth of the community energy movement (Roberts et al., 2014). In fact, renewable energy has developed through community initiatives. Municipalities have also historically played a role in energy supply, also dealing with spatial planning frameworks.

Public participation plays a central role in developing Denmark's wind power and district heating. According to studies, in 2016, about 80% of the installed wind power capacity was owned by citizens, while 96% of the district heating system belonged to the citizens.

Denmark is the leader in promoting district heating. Comparing district heating in different countries, it covers 6% in France, 14% in Germany, and 64% in Denmark of heating needs (Roberts et. al., 2014).

Denmark and Germany are the EU leaders in community energy projects . In particular, there are 1,750 Energy Communities in Germany and 700 in Denmark (JRC, 2020).

This approach has made Denmark an example of best practice. Therefore, an in-depth analysis is needed to discuss the active participation of the community. In this chapter, to analyze particular characteristics of the energy communities projects, an innovative semi-structured interviews is carried out.This section analyzes selected best practices to stimulate an in-depth **discussion** on the relationship between energy and spatial planning. This contribution will be a valuable reference for structuring the actions and plans proposed in Chapter 11.

Chapter 9

The Emilia-Romagna case

The Emilia-Romagna region with the Regional Law 26 of 2004 define “territorial energy planning”, articulating on three levels: regional, provincial, and municipal. The Emilia-Romagna case drives the evolution of Italian sectoral planning from a cognitive framework to the inclusion of energy issues in the normal planning process.

Specifically, the regional level is assigned the fundamental task of setting programmatic goals and guidelines and general criteria for its implementation at the territorial level. The provinces are tasked with providing for the formulation and implementation of program plans for the promotion of energy-saving measures, rational use of energy, and enhancement of renewable sources, and for the orderly development of facilities and networks of provincial interest. Municipalities are responsible for approving programs and projects for the energy qualification of the urban system.

In 2007, the Region equipped itself with the Energy Plan (PER) to affirm the principle of sustainable development of the regional energy system, specify general and energy policy objectives, and define the relevant lines of action in the implementation of which to have both public and private parties contribute. The latest Regional Energy Plan was approved in 2017, setting the Region's climate and energy strategy and goals for 2030.

9.1 PEC of Bologna

The **Municipal Energy Program PEC** of the Municipality of Bologna was drafted in 2007 (as required by Regional Law No. 26 of 2004) and updated by the Sustainable Energy Action Plan in 2012. The Plan set theenergy planning of the municipal territory to develop renewable sources and district heating networks.

The objectives indicated by the PEC must inspire all the city's transformation processes: an act of collective responsibility involving public bodies, businesses, and citizens as a Bologna pact for the environment.

An innovative element of Bologna's PEC is that it specifies 11 **Urban Energy Basin (BEUs)**, identified as having specific and relevant energy characteristics (integrated with others of an environmental and functional-urban type),defined in the urban plan Municipal Structural Plan PSC transformation areas.

Urban Energy Basins (BEUs), designed as shared analysis tools, are defined for homogeneous city areas through a combined set of energy, urban planning, and environmental cognitive elements. Through BEUs, **regulatory tools** ensure the reduction of energy consumption and energy qualification of the urban system by applying energy-saving interventions and renewable sources. The analyses carried out in BEUs highlight opportunities for applying energy performance standards in the design of new settlements or redevelopment of urban areas.

The spatial analysis on the Urban Energy Basins **integrate strategic areas** of the Energy Guidelines on New Build application. BEUs are areas of new urbanization, the district heating network, and infrastructural and natural boundary elements. Building energy efficiency scenarios from the Guidelines through action sheets is possible to integrate in a more or less cogent form in the governing instruments of new urbanization (POC, RUE).

This attempt to link aspects of spatial planning to energy issues shows some initial exciting insights and opportunities but also some critical issues. In fact, from the moment the BEUs coincide with or fall within, what are the **main urban transformation** areas in the plan, leading to three reflections (De Pascoli & Bagaini, 2019).

1. Energy values are within the broader hypothesis of settlement organization defined by the urban plan, and energy interventions are adapted to it, providing a **single integrated plan**. However, there is a lack of dialogue rather than just subordinate adaptation.
2. Energy interventions focus on specific areas (e.g., settlement organization, transportation, environment) **without** a **systemic vision**.
3. Since most refer to expansion areas, energy pools are proposed only for **new development areas** and ignore built-up areas.

Moreover, the most appropriate application scale is not the municipal scale, which fails to capture energy dynamics. Last but not least is the citizen **participation**. Through forums and workshops on projects, organized places inform and collect interested people's opinions. The forum aims to represent the interests of the citizenry in order to identify resources; this allows, in parallel, to identify possible conflicts between interests.

9.2 PRODEM di Modena

In the early 2000s, some local authorities in Emilia took the first steps toward integrating the energy variable into planning tools from the vast area to the urban scale. In Italy, until that time, the integration of energy sustainability objectives of development within land-use and urban planning tools did not find consolidated experiences at the vast area scale. With the preparatory study of Modena's PTCP (2009), **research** was applied for the definition of plan and regulatory tools to facilitate the application of systems for energy saving and the use of renewable sources, PRODEM.

9.2.1 Territorial Energy Basins (BET)

PRODEM research tried to outline a new methodological approach by defining energy guidelines in the form of a meta-plan and did so, for the first time, at a vast area scale. The meta-plan uses the **Territorial Energy Basins (BETs)**, forms of energy aggregation introduced by Law No. 10 of January 9, 1991, "*Norms for the implementation of the National Energy Plan on the rational use of energy, energy saving and the development of renewable energy sources*." Specifically, in Article 5, the definition is assigned to the Regional Energy Plans through which the regions "*identify the basins that about the characteristics, size, user needs, availability of renewable energy sources, achievable energy savings and the pre-existence of other energy carriers, constitute the most suitable areas for the feasibility of interventions for the rational use of energy and the use of renewable energy sources*." PRODEM is a **meta-plan** that provides site-specific sustainable development goals and contributes to preparing the State Territorial Coordination Plan (PTCP). In other words, define the areas where there is both **opportunity** and **demand** for **renewable sources** and, therefore, where policies and projects for the conservation and use of alternative sources are encouraged more than in other areas.

The entire Modenese territory has been divided into seven Territorial Energy Basins (BET), corresponding to the homogeneous areas of the PTCP, and the current and future energy demand and supply in terms of renewable energy sources available in the territory have been identified. This study appropriately introduces and addresses the concept of BET, which can be borrowed as a key for program planning.

9.2.2 Energy metaplan PRODEM

The spatial analysis of the energy system of the Province of Modena, served as the first basis for defining the subdivision of the territory into BETs. This was done through **aggregations of municipalities** and creating zones that are as homogeneous as possible within them, allowing for rapid visualization of the energy characteristics of the study area. This way, *spatial energy basins* are defined as areas with similar energy, topographic, settlement, and production characteristics. Besides being useful from an analytical point of view, it has obvious value in **targeting specific energy supply activities** and **actions** in terms of energy demand and supply. In addition, the study introduces a spatial **matrix** of **energy consumption** used to focus on the set of subsystems (components) associated with the selected observable parameters:

- Morphological, ecological framework: a unit created by the coexistence and interrelation of phenomena from different elements, such as climate, vegetation, topography, and waterways, in the same area, which can also be defined as a homogeneous natural or physical geographic area.
- Settlement characteristics: the relationships established between built and open spaces that define the shape of an urbanized area (e.g., central location, linear urban area, grid, large urban area, etc.).

The meshing of these elements as spatial and temporal keys with the geography of energy consumption contributes to the definition of the so-called spatial matrix of energy consumption.

Therefore, the purpose of the meta-plan is to define an experimental basis for an initial planning approach that can serve as an operational reference in the PTCP update phase. The PRODEM study identifies the stages that compose a "Metaplan" (Figure 42):

1. Analysis of **spatial matrix** at the large area scale that produces given types of energy consumption.
2. Analysis of **energy demand** in the territory and associated trends.
3. Analysis of the evolutionary relationship between the regional consumption matrix and energy demand.
4. Analysis of **energy supply** for each renewable energy source (power plants operating with programmable and non-programmable renewable energy sources, hybrid power plants, and micro power plants).

These first steps make it possible to outline the minimum contents of the knowledge framework to support the meta-plan and define the energy framework of the province and its organization into territorial energy basins.

5. For each territorial energy basin, in terms of demand and supply (current/scenario), define **specific objectives** for the promotion of energy efficiency, use of renewable sources, and energy conversion, as well as **general guidelines** for the energy sustainability of the settlement system compatible with the energy characteristics of the basin.
6. Identify **unsuitable areas** and criteria for the **location of renewable energy power plants** (through overlapping resources and defined exemptions for local environmental and landscape constraints defined in existing planning and legal instruments) and non-renewable resources (regional sensitivity analysis).

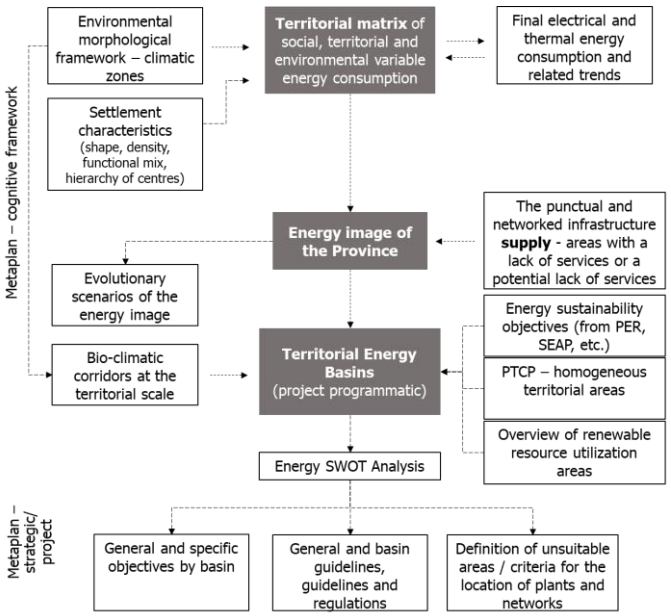


Figure 42: Structure and relationships of the metaplan.

In conclusion, identifying BETs has enabled the establishment of specific goals for promoting energy efficiency, renewable energy use, energy sustainability guidelines and regulations, settlement system guidelines, transformation, land use, and urban environmental quality standards. One of the limitations of this new spatial allocation is the **absence** of an adequate **execution system** and **monitoring** of plan decisions. Moreover, the tendency to define and plan without fully considering the **energy production uses** of the supply sector in question. In fact, the plan fail in considering the temporal variable of energy (production and demand profiling). In addition, it doesn't set strategies and actions for promoting the development and formation of territorial energy communities, affecting the organization of citizenship.

Chapter 10

The Danish case

In literature, there is general agreement that to implement a **democratic** and **shared** energy transition, the support of the **local community** is needed (Goedkoop and Devine-Wright, 2016). The concept of energy democracy is fluid and flexible, which allows researchers to interpret it depending on the specific situation. However, to improve communication, conceptual clarity needs to be developed (Szulecki & Overland, 2020).

Implementing a socially just energy transformation requires the active participation of communities by making them part of new renewable energy projects, with the goal of independence from the fossil fuel (REScoop.eu). Community participation leads to acceptance of renewable energy diffusion, a key barrier (Jobert et al., 2007). Therefore, it is crucial to understand how forms of cooperation are born and can be supported (Mey & Diesendorf, 2018).

A model of local energy cooperation has long been developed in **Denmark** since the **1970s**, where decentralised energy generation systems based on RES and local grids are widespread, with significant household support. Today, public participation is central to Denmark's wind power and district heating development scheme. Community energy generation, mainly focused on wind, now occurs predominantly in partnership with energy utilities. Studies have estimated that in 2016, **citizens owned** about **70%** of the total installed **wind power** capacity. Meanwhile, the **district heating** regulated by non-profit rule, which makes investments unattractive for external investors and attractive for consumers, benefits from lower energy bills account for **96%** of **citizen ownership** (Gorroño-Albizu et al., 2019).

10.1 Danish spatial planning system

This section supplies a brief introduction to spatial and energy planning in Denmark, an analysis of the Danish contest about the theme of cooperation, and an

in-depth look at co-production. This will be essential to contextualise the Danish case under analysis, compare it with the Italian context, and analyse how energy cooperation fits into comprehensive spatial planning.

10.1.1 Administrative structure and governance system

Denmark has a population of about 6 million, very different from Italy, which has about 60 million. Recently, Denmark has drastically reorganised its public sector following the **Local Government Reform** Act of 2005 and its enactment in January 2007. The 14 counties (*amter*) that were the administrative units on the mainland were abolished and remodeled into 5 regions, administrative units covering more expansive areas. Services have been transferred to the central government and municipalities, which has made the regions' activities more limited than those of counties, and the health sector has become the primary service provided by the regions.

In the past, the responsibility for national land use planning was shared by three administrative levels: central government, counties, and municipalities. However, after the abolition of counties, the power of regions was reduced, this responsibility became shared by two levels. The central government sets the general planning guidelines, while municipalities translate this vision into practice through municipal and local plans. The Planning Act (*Planloven*) establishes the framework of legal regulations for local planning in Denmark. The law integrated and simplified planning and zoning regulations by dividing the country into three zones (urban, rural, and summer village areas). The rationale behind it is to protect the rural areas.

This reorientation has been accompanied by less state involvement in land-use planning affairs and, thus, a reduction in the state's power to oppose municipal plans (Danish Business Authority 2018). The region handles producing the **regional development strategy** (*regional udviklingsstrategi*) and the regional commodity plan (*regional råstofplan*). The municipality (*kommune*) is the main spatial planning agent in Denmark. It handles the production of municipal spatial strategies (*planstrategi*), **municipal master plans** (*kommuneplan*), and **detailed local master plans** (*lokalplan*).

10.1.2 Energy planning

The short-term goal for the city of Copenhagen is a **zero-carbon energy** supply by **2025**, while the long-term goal for Denmark is **100% renewable**

energy by **2050**. Copenhagen will play a vital role in these ambitious goals in this transition. In Denmark, achieving 100% renewable energy is feasible with a Smart Energy System approach that requires local participation. "*Smart Energy System*" refers to the term developed by Lund et al. (2017) to describe a fully integrated renewable energy system where electricity, heat, and gas are combined and coordinated to find synergies to achieve the best solution. This case study is particularly relevant to Copenhagen, which has been transitioning from the existing planning paradigm to a "resilient city" strategic process since 2012 (Scalas & Faravelli, 2021).

Energy planning is regulated primarily by the **Energy Act** (*Energiloven*) and the **National Energy Plan** (*Energiaftalen*). The *Energiloven* sets the rules for energy production, transportation, and consumption in Denmark and defines long-term goals for transitioning to a low-carbon economy. The national energy plan (*Energiaftalen*) is an agreement between the government and parliament that sets long-term goals for clean energy production and increased energy efficiency. In addition, some other laws and regulations set specific aspects of energy planning, such as the **Energy Efficiency Act** (*Energistyrelsens bekendtgørelse* nr. 1464 af 15/12/2020), which sets standards for energy efficiency in buildings, and the **Renewable Energy Act** (*Vedrørende vedvarende energi*), which sets targets for renewable energy production and rules for investments in renewable energy sources.

The Danish government introduced the concept of **strategic energy planning** in 2012 through the Energy Accord. However, according to the literature, the strategic energy planning approach has been slowly integrated into the energy planning system. In 2010, strategic energy planning was introduced. The definition focuses on **municipalities** as central and on the **technical aspect** (planning tools) of the energy system (Prasad et al., 2014).

The Danish Energy Agency has produced two guidelines to support strategic energy planning in municipalities. Guidelines on mapping and data collection (Energistyrelsen, 2012) and guidelines on system change analysis and scenario analysis (Energistyrelsen, 2016) emphasize the importance of the **central government** in **supporting** these types of initiatives. The guidelines should be seen only as guiding principles for guiding municipalities and voluntarily using the methods described in the guidelines.

10.1.3 Danish cooperation context

The Danish cooperative movement (*Andelsbevægelsen*) appeared in 1790 in **rural communities**, starting from the agricultural sector and influencing Denmark's economic, organizational, and industrial development. The cooperative movement is a society controlled by consumers or producers in which each member owns a part of the society (share). Members share the economic stress of producing or buying goods and redistribute any surplus among themselves. Ownership rules in cooperative societies vary considerably: some share financial risk equally, while others give more power to those most financially involved.

Housing policies in Denmark have been in place since 1919, when a national system of public social housing was instituted, supported by broad political and public support. Nonprofit housing development is integral to Danish welfare policy; social housing accounts for about 20% of Copenhagen's housing stock. Market-rate housing and rentals make up 43%, while private cooperatives account for another sizable part. About 30 % of the residential property stock of Copenhagen is composed of private cooperatives (coops). This housing structure has a long tradition in Denmark, where tenants buy a share in the cooperative, giving them the right to live in one of the apartments. Since cooperative tenants collectively own their units, expenses for routine maintenance and substantial improvements are also shared collectively, meaning that decisions must be mutually agreed upon.

The Social Housing Act allows tenants to participate in self-government through "tenant democracy actively." Following the Consolidated Act on Social Housing of 2009 and other related provisions, tenants living in social housing complexes are considered members of the association and handle the management of the complex. This responsibility includes decisions about maintenance, budget approval, improvements, and repairs, making internal rules, managing communal areas, and organizing social initiatives.

10.1.4 Co-production

Involving local communities in the urban and regional planning process is crucial in setting priorities and goals. Communities can supply local knowledge that can guide planning decisions. In addition, involving communities in the planning process can help build the trust of local and regional authorities, improving the quality of local democracy. However, significant challenges in involving

communities in urban planning include overcoming inequalities of power and resources among the different actors involved.

This work uses the concept of **co-production** as the **"***active participation of communities*" (private) "*sharing responsibilities with institutions*" (public) "*within a specific framework of public rules*". The concept of co-production, introduced by Elinor Ostrom, involves citizens collaborating with public agencies and professional and managerial staff to supply public services. This concept means that citizens are not only beneficiaries of services but also active participants in designing, implementing, and evaluating those services. (Brandsen & Pestoff, 2008; Brandsen & Honingh, 2016).

According to the Trades Union Congress report, co-production can benefit citizens and public agencies. These benefits include an increased ability to get to the source of problems and develop customized solutions, increased innovation and efficiency of services around user needs, increased user satisfaction, more cohesive communities and a sense of local ownership, building trust and capacity of individuals and communities; and better use of public resources (Brandsen & Honingh, 2016).

Brandsen and Pestoff (2008) highlight that the **critical factor** is the need for clear and open communication between all parties involved and a shared understanding of goals and aims. It is also essential to establish trust and build relationships between the third sector and government agencies that can bring unique skills, knowledge, and resources to service delivery partnerships, enhancing the quality and effectiveness of services. The article (Brandsen & Honingh, 2016) finds several types of co-productions, according to the degree to which the citizens are involved in designing the services they receive and whether the co-production involves the organization's core services or complementary activities.

Brunetta and Moroni (2012) highlight how contracting communities promote freedom and creativity by adopting practices of self-organization and self-governance. These communities look to create spaces where members can freely express their ideas and experiment with innovative solutions to community problems. In addition, contract communities try to decentralize decision-making power, allowing members to participate actively in community management. The paper suggests that a public rules framework is essential to ensure the effectiveness and justice of contract communities.

The article (Habermehl & Perry, 2021) explores the challenges and opportunities associated with community involvement in the Greater Manchester Spatial Framework (GMSF) planning process. It examines how different stakeholders perceive and consider community input. In the context of the article, the concept of austerity refers to the situation where available resources (e.g., public funding) for urban and regional planning are limited or declining. Although co-production stays promising, austerity-related co-production risks functioning as a predefined solution to urban problems that limit more innovative approaches to city-region governance and policy.

In (Bragaglia, 2021), a critical reflection on the concept of social innovation can be defined as a "magic concept" for urban governance as theorized by Pollitt and Hupe. Indeed, **uncritical use** can lead to oversimplification of complex social problems, delegation of responsibility from the state to civil society, and reduced democratic participation and political representation.

10.1.5 Conclusions

The primary laws that regulate land use planning in Denmark are the **Spatial Planning Act** and the **Land Use Act**. The Spatial Planning Act establishes rules for land use planning at the regional and municipal levels. In addition, the law establishes rules for public participation and stakeholder consultation. The Land Use Act is a law that establishes rules for land use and building construction.

The Danish planning system has three basic principles: **decision-making** framework, **decentralization**, and **public participation.** However, regarding the land use allocation system, Denmark corresponds to a **neo-performative model** (Rivolin, 2016). In this type of allocation system, as in the conformist one, plans are legally binding, but they are drafted after plan collection, checking, and further negotiations with operators (Rivolin, 2016). Whereas the conformist planning system, the Italian system, is characterized by binding zoning, the urban transformation strategy is included in a master plan. This approach called the "prescriptive approach," interprets land-use planning as an activity in which land-use laws constrain areas according to a defined minimum value of public spaces, unlike the "descriptive approach," which interprets "standard" as a minimum term in reference.

These two approaches tend to urban comfort planning, which leads to a shift from a traditional separation of responsibilities between public and private to a new

allocation of responsibilities. In this context, "*spatial planning is no longer a controller but an active participant in urban processes*" (Portugal, 1999).

Denmark's governance system for spatial planning is characterized by solid **cooperation** between **levels** of government**,** emphasizing the **active participation** of **citizens** and local communities. The central government supplies the guidelines and funds for urban and spatial development, while local and regional authorities handle planning and managing development on the ground. Spatial planning is the responsibility of different government agencies that deal with specific aspects of spatial development. In this case, intersectionality in spatial planning is a strong collaboration between government agencies and various levels of government. This makes it possible to integrate spatial issues into a global perspective and to consider the long-term effects of decisions.

The Italian governance system for spatial planning has a hierarchical structure, with the central government holding most of the decision-making power and local authorities having a more limited role. Urban and regional planning has solid centralization and a need for coordination between government levels.

10.2 Case study analysis

To better analyze the topic of the research work, community energy in Denmark, a study trip was made to interview key players in the most relevant cooperatives and researchers working in this field.

These interviews aimed to find, through a structured questionnaire that covers four macro-themes, the key elements that contributed to the creation of these energy cooperatives. Investigating: the models or forms of cooperation adopted, the process of population aggregation, the management of the economic aspects, the integration of these forms of cooperation into spatial planning, and the technical operation of these cooperatives.

10.2.1 Case studies and interviewees

The case studies analyzed include the Middelgrunden wind farm (represented by Hans Chr Soerensen), Avedøre, located in the municipality of Hvidovre (represented by Charlotte von Hessberg), the island of Samsø (represented by Søren Hermansen) and the municipality of Middelfart (represented by Morten Mejsen Westergaard). These case studies were selected to supply a representative picture

of cooperatives in Denmark, presenting different contexts and solutions that have been successful in the country's energy transition. These cooperatives have the following distinctive characteristics.

The Middelgrunden wind farm, built in 2000, was the **world's largest offshore farm**. It features 20 turbines, each with a capacity of 2 MW Bonus, generating 40 MW. It is **50%** owned by 10,000 **investors** in the Middelgrunden Wind Turbine Cooperative and **50%** by the municipal **utility company**.

Avedøre, in Hvidovre Municipality, is the **first Energy Community** following the new EU directive. Hvidovre is a cooperative comprising 250 members and 33,000 consumers, including the Hvidovre municipality, **supplying renewable heat** to its inhabitants. Together with three other district heating cooperatives (Hvidovre, Avedøre, and Rebæk Søpark), they implemented a program to help members **perfect their heating installations**, resulting in energy and cost savings.

The island of Samsø has achieved a remarkable feat by transforming its entire energy system from fossil fuels to renewable energy. It has become the world's **first renewable energy island**. The island's transition to renewable energy has resulted in several significant achievements, such as achieving carbon negativity, 100% local ownership of renewable energy investments, and numerous socio-economic benefits. These benefits include addressing unemployment and population decline resulting from the energy transition.

The Green Energy Communities of Middelfart Municipality were the first Municipalities' Climate Prize recipients. These local energy communities are **managed by citizens themselves**. Among the examples is "Sol-Over-Brenderup," a solar park invented, started, run, and owned by citizens in the small town of Brenderup. In the village of Føns, citizens have renovated and established their local heating system based on geothermal heat and residual wood, **collaborating** in a completely **new way**. In order to raise the budget needed to realize the project, the municipality is testing a **self-made crowdfunding platform** based on co-creation with citizens.

10.2.2 Methodology

The method adopted for this research involved interviews with representatives of the selected energy cooperatives and several researchers and experts in the field (Ulrik Kohl, Irina Papazu, and Ulrik Jørgensen). During the interviews, a **semi-**

structured questionnaire addresses four specific macro themes. The issues to be investigated were specific and predefined in relation to the topic of community energy projects, therefore to obtain direct responses on the topic, the semi-structured interviews was chosen. The choice was influenced also by the available timetable and the intention to investigate a set of case studies for a greater range of comparison.

Semi-structured interviews are useful for addressing complex issues, allowing for an insight and clarification of the topic being investigated (Wilson, 2014). In qualitative research they are a valuable tool, particularly when conducting interviews abroad (Horton et al., 2004).

A semi-structured interview is a guide that serves as a list of topics to be covered, with predefined questions regarding formulation and order. Since the semi-structured interview aims to explore the field, most of the questions are open-ended, allowing for in-depth responses and subjective opinions. However, it is essential to note that the questions may have some inherent bias due to their formulation. In addition, participants did not need to know all the answers to the questions, and the purpose was not to compare responses. Therefore, the responses were used as a **starting point** to initiate discussion and identify themes further explored through the literature review.

The interviews were recorded following the consent of the participants. The main advantage of the recordings was that it was possible to focus on conducting the interview and answering follow-up questions without taking detailed notes. Since the interviews constituted the basis for the questionnaire, they were not transcribed entirely, but by selecting the passages considered most relevant with particular attention.

10.2.3 Results

Form/model of local energy cooperation

The notion of **community energy** can assume different connotations, and by REScoop.eu (the European Federation of Citizen Energy Cooperatives), it can generally be defined as any project or initiative in which people own or take part in managing renewable energy or related services. Therefore, community energy can take different forms depending on the activity. The legal forms used vary from cooperatives, partnerships, corporations with a community interest, foundations,

nonprofit organizations, trusts, and associations (Roberts, J et al., 2014). This form depends on people's needs and the country's relevant regulations.

Cooperatives are the most common organizational form; they are "democratic" structures that follow internationally agreed principles and make decisions based on a one-person-one-vote system with daily operations by an elected board (REN21). Generally, they allow moderate returns to investors and require fewer administrative and legal requirements than a private company.

Partnerships are another common legal entity; these organizational forms tend to be governed by a board of directors because ownership rights depend on each partner's financial investment, mainly in the form of shares (REN21). The advantages of adopting this model include

- the ability to take advantage of certain tax benefits,
- the fair distribution of responsibilities and profits, and
- the ability to ensure a more democratic and transparent decision-making process than a traditional corporation.

Other legal forms may include nonprofit corporations, foundations, and trusts. Nonprofit corporations that can run in the form of nongovernmental organizations (NGOs) follow the framework of cooperatives by adding some specific rules. For instance, the organization's rules might say that ownership may require connection to the grid, or votes may be restricted to limit who own multiple properties. (REN21).

In **Denmark**, the most common community energy projects are general partnerships (*Interessentskab*), also known as wind turbine corporations (*Vindmøllelaug*), commonly known as cooperatives or wind *guilds*. This association has deep roots in Danish society, but in practice, they are partnerships. It usually happens that utilities own large projects, while smaller projects belong to cooperatives or farmers' associations. Over time, there have been changes in turbine production, with the emergence of a specialized industry that has developed more advanced and larger turbines and ownership patterns that have attracted professional investors because of increasing expectations of profitability. These changes, induced by policy adjustments, have gradually weakened links with the alternative energy movement in recent years (Olesen et al., 2004; Jørgensen & Karnøe, 1995; Boon, 2008).

Drivers that Guide Local Energy Cooperation

The cooperative development and diffusion of renewable energy in Denmark since the 1970s is a best practice. In the early years, this spread on **citizen-driven** bottom-up initiatives, driven by several factors, including the strength of the antinuclear and alternative energy movement with a gradual small-scale development. Thrusts were accompanied by gradually emerging and continuously adapted **political support** (Danielsen, 1995; Kemp et al., 2001; Jørgensen & Karnøe, 1995). Many authors agree that feed-in regulations, standardized rules for grid connection, and tax breaks are factors that have favored the development of community wind projects (Bolinger, 2001; Olesen et al., 2004). In this, capital mobilization aimed at **financial support** of community energy has played a relevant role. An example of this could be implementing favorable conditions for access to loans and insurance (as suggested by Olesen et al., 2004) and adopting specific forms of co-ownership between local private actors and investors (Bolinger, 2005). In conclusion, the importance of **cultural factors**, particularly the existence of an alternative energy movement and familiarity with cooperative ownership structures, was emphasized as one of the basis characteristics by interviewees and authors (Bolinger, 2001).

From the interviews, the success of the Danish case studies in terms of public participation is due to two key factors: the local nature of the initiatives and the active participation of community members. Unlike projects imposed outside, these initiatives appeared organically within the communities themselves. The desire for local benefits, such as job creation and increased dynamism, drove them. These projects were particularly successful because people were genuinely invested in them. They saw the potential positive impact on their lives and community, motivating their participation. Environmental concerns did not solely drive it, but also the tangible benefits the projects could bring.

At the same time, when a cooperative is legally recognized, the driver is not to generate financial profits but to improve the community's living conditions. This means that cooperatives' profits go directly to their members or invest in projects that improve the community's natural, social, or economic environment (Rescoops - Renewable Energy Source Cooperatives).

It is also important to mention the role of **intermediaries** who mediate the relationships between community members, investors, and institutional bodies. In the case of Samso, the Energy and Environment Office, an NGO, played a crucial role in translating the master plan into local action. They implemented innovative tools to prevent conflicts related to wind farm developments. For example, one

approach they used was to negotiate agreements with landowners. These agreements ensured landowners would receive support to obtain a wind turbine on the condition that they would offer a share of the purchase to the surrounding villages. This helped to foster cooperation and minimize potential conflicts. The Energy and Environment Office acted as a bridge between different stakeholders, easing communication and ensuring the consideration of the interests of all parties.

Economic Management

In Denmark, the most common business model is the **partnership**. In this model, each partner is responsible for the entire partnership debt, making them individually liable at a legal level. This means that there is a higher risk involved. However, it can be reduced by prohibiting the partnership from incurring debt, underwriting it in the statutes, and requiring insurance for the project as security. Unlike a cooperative, creating a partnership also allows individuals to be taxed at a favorable rate for investment returns. These returns are correlated with average household consumption.

The **community foundation model** is used to create a community fund in which profits from renewable energy production finance local development. For example, Wind People, a local NGO, pioneered the project, which resembles a trust fund. At the same time, **district heating** is usually a **nonprofit corporation** owned by customers supported by the municipality. In Denmark, this model is a unique model of community leadership in renewable heating development that has been remarkably successful and has not severely limited the entry of large investors.

Finally, in **municipal participation**, if a public authority has administrative powers over service provision, it must manage its activities through a separate company. Most are public limited liability companies (*Aktieselskab* - A/S) or private limited liability companies (*Anpartsselskab* - ApS). These are spread throughout the country to ensure investment in supply and infrastructure. To prevent them from obtaining a dominant position, the Electricity Supply Act restricts the use of profits from selling electricity to finance activities related to the original business.

Managing in Spatial Planning

The regulatory framework in Denmark for siting wind turbines is of two categories- onshore and offshore. The responsibility of onshore wind turbine siting lies with the municipalities, except for more giant onshore wind turbines above 150

meters, where the Ministry of Environment takes charge of Environmental Impact Assessment (EIA). On the other hand, the responsibility of offshore wind turbines lies with the Danish Energy Agency (*Energistyrelsen*).

On the municipal scale, the spatial planning of wind turbines is **strategic** and **project planning**. Strategic planning identifies suitable locations for wind turbines based on municipal or thematic plans. This involves following mandatory guidelines and framework provisions set by the municipality, determining the maximum number and size of turbines, establishing minimum distances from neighboring properties, and assessing the potential impacts on the surrounding landscapes. At the same time, the project planning is on detailed planning for individual wind energy projects with the local plans: precise siting, number, height, and design; minimum distance to neighbors; and landscape assessment. Permit requirements for onshore plants: EIA permit, rural zone permit, Building Act notification, and other permits (e.g., Nature Protection Act, Forest Act). For offshore: preliminary investigation permit, establishment permit, operation permit.

Spatial planning has been identified as a **critical factor** in the successful implementation of wind energy by various authors, including Olesen et al. (2004). In Denmark, the adoption of preferential land-use planning regulations supporting wind energy development has increased the rate at which new plants are being installed. However, this has also resulted in more significant opposition, prompting some experts to call for more participatory planning approaches.

In order to enhance **local acceptance** of wind turbine projects under the Renewable Energy Act (2009), four policy measures were introduced:

- The neighbor compensation scheme (obliges wind energy developers to compensate neighbors for loss of property value greater than 1%).
- The co-ownership scheme (obliges wind energy developers to offer a minimum of 20% ownership shares to residents).
- The community benefit scheme (provides funding for local projects that improve landscape or recreational values or promote cultural and informational activities).
- The guarantee fund for local ownership initiatives (provides loan guarantees for preliminary surveys by local wind turbine owners' associations.

Local participation in planning is also an essential aspect of institutional ability building. Authors have analyzed the "NIMBY approach," pointing out that local opposition stems not only from aesthetical objections but also from objections to specific forms of decision-making and distribution of economic benefits.

Technical functioning of the cooperation

Unlike the Italian case, in Denmark, energy meters that account for energy flows are distributed throughout the country, easing the tracking of energy flows and evaluating energy incentives. The spatial dimensions of the projects analyzed differ in each case; mainly, they are the physical size of the grid extensions.

Like Italy, Denmark also faces barriers outlined in the new Renewable Energy Communities law. These obstacles include the complexity of the energy communities and distribution network legislation. This highlights the importance of clear definitions, fair tariffs, and consideration of local community dynamics. These barriers contradict the interests of sizeable cooperative grid companies and emerging citizen energy communities.

Conclusions

Growing local opposition to installing new renewable energy facilities highlights the importance of adopting local participation and ownership as a solution. The approach known as "NIMBY" has shown that opposition to wind energy is not only based on esthetical reasons but also objections about specific decision-making processes and the distribution of economic benefits. The participation of the local community in planning and community involvement in the ownership of the community are key elements in strengthening the institutional ability needed to implement a sustainable energy system based on renewable energy sources.

The work pointed out that several factors, including support mechanisms for renewables, planning policies, and local culture, decide the spread of renewable energy cooperatives. Administrative and planning procedures can influence the willingness of cooperatives to undertake such projects, especially when small projects are involved. Therefore, according to Schreuer and Weismeier (2010) and the European Union report (2018), the following are defined as critical factors for success in developing local energy ownership models:

1. **Stable policies** and **political support** for renewable energy and the energy transition.
    - Clear political commitment to stable policies and financial support mechanisms for renewable energy.
    - A clear legal framework with rules that ensure fair market access for local energy communities.
2. **Targeted promotion** of local energy communities**.**
    - Recognition in policies and legislation of their specific role and needs.
    - Establishment of rules and policies that promote local collaboration.
    - Adoption of simplified and proportionate regulatory and administrative procedures.
    - Facilitated access to technical information, guidance, and funding.

Factors related to the existing context, such as culture, familiarity with cooperation, and shared ideologies, are the starting points for forming cooperatives. Finding competent social actors and creating governance structures consistent with the envisioned forms to guide collective action is also essential. Then, the state must ensure a perspective of stability with long-term strategies.

Chapter 11 Next Generation Energy Plan

The energy sector produces two-thirds of global emissions of climate-changing gases (IEA, 2015). Around 80% of energy consumption and CO2 emissions in Europe are linked to urban activities (EEA, 2013). Therefore, the energy sector is the primary source of global emissions, which holds the key to solving the issue of climate change.

The solution to achieve a more resilient energy system is to change the paradigm of spatial energy management from centralized to **diffused energy production systems** (Realising Transition Pathways, 2015). The research, therefore, focused on renewable energy sources, resources practically inexhaustible but limited for:

- dispersed nature of energy sources with considerable dimensions,
- limited availability in time and discontinuity of generation,
- accessibility related to the presence of constraints of a different nature.

Highlighting that trend that foresees RES growth (PNIEC, 2019) **must be planned** on the territories. Energy communities are an **opportunity** to guide the energy transition of territories and increase the integration grade between energy and spatial planning. The work focuses on the Italian context, where energy topics and spatial planning are treated sectorally without communicating (De Pascali & Bagaini, 2021; Zanon & Verones, 2013).

The work sets technical and planning goals. The **technical goals** are working on models and tools for analyzing energy systems at an urban scale with a place-based approach, such as finding the optimal dimension and spatial distribution of ECs throughout territories and identifying the most effective energy policy for each territory through future scenarios evaluation. The **planning goals** are planning spatial-energy strategies to enhance multilevel coordination among public authorities, such as defining different policies to encourage the creation of energy communities and integrating the ECs into spatial planning as a driver of the energy transition.

The work constructed theoretical (Part I) and cognitive framework (Part II) bases that allow the implementation of a decision-making tool. Pre-planning mechanisms allow for consideration of regulatory aspects, environmental constraints, and socioeconomic aspects; they could also help streamline and speed up the permitting process for RES plants.

The proposed plan applies a restyling in the architecture and methodological approach of the ordinary planning tool at a vast area scale. In particular, it offers an energy-oriented meta-plan that uses the Territorial Energy Basins as a guiding structural element to implement specific strategies. Analyzing the four critical characteristics of a spatial energy plan led to identifying solutions to overcome energy planning barriers.

The following sections outline the results of a proposed for the next generation energy plan. The meta-plan **proposal** establish a framework for future energy plans. The results show the implemented approach to integrate the energy component into ordinary spatial planning. In conclusion, in order to overcome energy planning barriers the next-generation energy plan must be based on four **pillars**. These pillars provide a valuable foundation for future energy plans and identify solutions to help territories achieve sustainable and efficient energy management.

Proposal for a meta-plan with energy-related value

The energy-oriented meta-plan outlined in this chapter uses the PRODEM of Modena, the plan of Bologna, and the case of Danish community projects as a framework. It aims to build on their strengths and address their weaknesses, taking a step forward in the debate on the interaction between energy and spatial planning in the Italian context. The research suggests using a vast area scale to face the various energy variable characteristics effectively and as a strategic application scale (refer to Chapter 4.5). Thus, the PTGM of the Metropolitan City of Turin is a reference point for implementing the proposed solution.

It is essential to note that **planning** and **meta-planning** address different issues at two levels (Campaign, 2016). Planning is defining concrete, circumscribed actions requiring specific knowledge (e.g., empirical information). Meta-planning is about defining a **public institutional framework** and thus defining a clear and shared division of responsibilities between spatial government levels; it requires "meta-knowledge" (e.g., knowledge of how decision-making processes take place and the spatial dynamics that lead to the aggregation of territories) (Moroni et al., 2023).

11.1 Structure of the Metaplan

Figure 43 shows the flow chart structure of the energy metaplan. The structure comprises three main components: a knowledge framework, planning tools, and a strategic planning section. The **analytical framework** carried out a process that included an analysis of energy demand, production, and producibility at the vast area scale. This analysis identified areas with higher energy consumption or production and those with the most significant potential for renewable energy production. Moreover, the energy flows were profiled during different time steps, and the electric infrastructure supply was analyzed. At the same time, the environmental and morphological framework, the socio-economic characteristics, and the build-up characteristics were analyzed at the vast area scale, implementing a territorial matrix.

The analysis of the **planning tools** creates the meta-knowledge of how decision-making processes occur and the spatial dynamics that lead to the aggregation of territories. Starting with the energy image of the Metropolitan City of Turin, the analysis of the PTGM was oriented to investigate the integration of the PTGM energy standards and using the PTGM – Homogeneous Territorial Areas as a reference for testing the Territorial Energy Basins (BET).

Finally, using the analyses and tools, **spatial energy goals** and **strategies** were defined based on municipalities' aggregations.

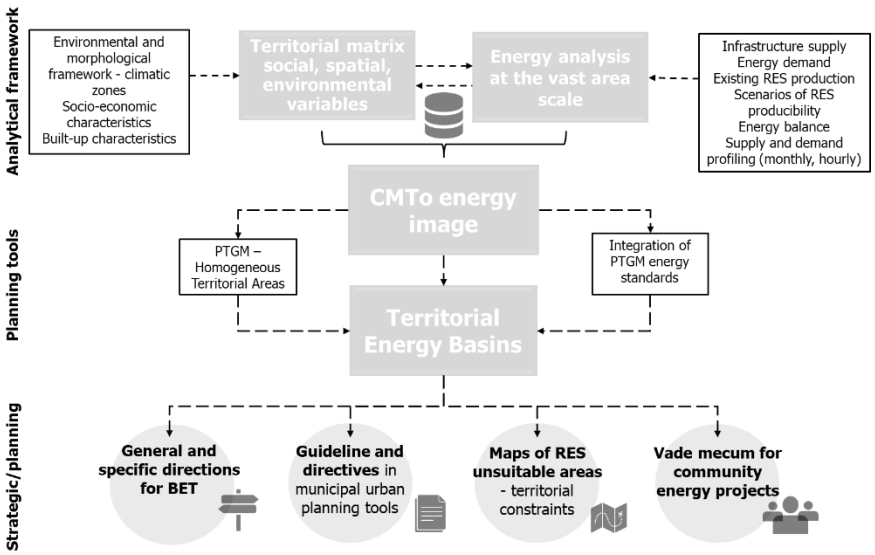


Figure 43: Flow chart structure of the energy metaplan.

11.2 Energy guidelines

The following chapter intends to experiment with the guidelines of a Metaplan that incorporates energy sustainability goals and contributes to the strategies of the Metropolitan General Plan (PTGM) of the Metropolitan City. This experimentation wants to stimulate discussion and activate attention to the "energy and territory" relationship.

11.2.1 The Metropolitan General Territorial Plan (PTGM)

Law No. 56 of April 7, 2014, Provisions on metropolitan cities, provinces, unions, and mergers of municipalities assign metropolitan cities the fundamental function of general territorial planning. The Metropolitan General Territorial Plan (PTGM), by let. b), co. 1 Article 3 of LR 56/77 and Article 8 of the Metropolitan Statute also assume the value of the Territorial Coordination Plan for all effects. The aims and contents of the PTGM are defined by Regional Law 56/77 and regional general planning instruments, starting with the Regional Territorial Plan and Regional Landscape Plan. In particular, the PTGM defines:

1. The portions of the territory to be subject to a **particular discipline** and the **safeguard criteria** for protection of primary resources, defense of the soil from hydrogeological instability, prevention, and defense from

pollution; protection and enhancement of landscape, cultural and environmental assets, parks, nature reserves, areas of landscape and tourist interest.

2. The **localization criteria** for infrastructure networks, services, equipment, and production facilities, with particular attention to transportation, telematic networks, and production and commercial activities of **the supra-municipal level**.
3. The **criteria**, **guidelines**, **directives**, and **prescriptions** that prevail over municipal urban planning regulations (prescriptions binding on private individuals).
4. The cases in which their specification or implementation is subject to the formation of Operational Territorial Plans, also identifying the relevant area.

The PGTM of the Metropolitan City of Turin uses the organization in 11 homogeneous zones as a territorial aggregation to implement its strategies. These zones divide the territory into areas with similar characteristics to facilitate the implementation of specific policies in accordance with the territory's characteristics. They were chosen as the territorial reference dimension because they proved optimal for defining local development strategies, considering the considerations made so far.

11.2.2 Energy directions of the plan

It is essential to identify how the PTGM applies the cogency of a plan to understand how decision-making processes take place and implement the integration of PTGM energy standards. The PTGM applies cogency as follows:

- **Prescriptions** that immediately prevail over municipal regulations and are binding on private parties.
- **Directives** that require transposition into local planning and require implementation.
- **Directions** and criteria orientation.
- **Guidelines** indications of a technical/procedural and management nature.

The work proposes normative guidelines that contain **operational dispositions** for the **adaptation** of the PTGM, considering the energy issue and the structure of the supra-municipal plan. The following normative references

constitute an initial test phase for integrating the energy component within the tools of territorial government. Some insights, rather than a complete normative text, are presented that relate to the structure of the PTGM and its functions to promote moments of reflection and discussion. Finally, the experimental proposal adopts the mainstreaming adaptation approach to energy resilience, which considers introducing measures and actions for transition, adaptation, efficiency, and green network conversion into ordinary spatial and urban planning tools. In particular, the energy directions of the proposed meta-plan are as follows.

A. Goals and targets of the PTGM

The Metropolitan General Territorial Plan (PTGM) is a plan that aims to achieve various goals and objectives in the energy field. In addition, the PTGM is the supra-municipal scale plan that declines the strategies and actions provided by the Metropolitan Strategic Plan PSMTo, assuming value as a PTCP. The plan's main objectives include encouraging renewable energy production, development of local community solutions, encouraging energy upgrading of existing buildings, promoting sustainable mobility, encouraging the creation of efficient distribution networks, promoting sustainable waste management, and encouraging energy planning at the territorial scale.

A.1 Content of the PTGM

The PTGM refers to the **regional level** to integrate the energy theme into the Regional Environmental Energy Plan (PEAR, adopted dGR No.10- 6480/2018). It is a reference for the energy theme aimed at achieving the objectives of the European Strategy for 2020 and 2030. In addition, it refers to L.r. 12/18, which promotes the establishment of energy communities.

At the level of the **Metropolitan City** to the Sustainable Energy Action Plan (SEAP, DGP 50533 of 21.1.2014). Instrument that defines the quantitative targets for reducing energy consumption, using renewable sources, and reducing climate-changing emissions by 2020; the energy strategy and intervention actions can achieve these targets. In addition, it refers to the Covenant of Mayors, January 29, 2008 (EUSEW). Finally, the Sustainable Energy Action Plan (SEAP) is at the **municipal level**. Local reference for energy issues. Covenant of Mayors, January 29, 2008 (EUSEW). The following are the normative references in the PTGM that refer to the energy component:

- Art. 18 - SOSURB - Sustainability and quality in urban settlements and facilities
- Art. 34 IPE - Energy production facilities.
- The Action (Azo2_1Ta) supports disseminating renewable energy and developing local community-based solutions.

In summary, the PTGM promotes experimentation with sustainable energy solutions to improve the resilience of urban areas. It also supports municipalities in developing renewable energy and can work through constructing a metropolitan competence center. In addition, it defines criteria for the location of energy production facilities, preferring brownfield or compromised industrial areas and defining "preferable areas," "neutral areas," and "problem areas" for the location of hydropower plants. Finally, it supports the deployment of renewable energy and the development of local community-based solutions. Energy is addressed superficially without delving deeper into the subject. This approach suggests the **need to develop area-specific strategic directions**. The Metropolitan General Plan outlines three themes for energy sustainability: reducing resource consumption and improving residential and productive settlement systems and facilities. The strategies for each theme are summarized below:

- Soil and resource consumption aims to limit land use and build non-dispersed urban areas. The Territorial Transformations Observatory tracks land use and ensures environmental sustainability.
- The residential settlement system aims to maintain open spaces and affordable housing and improve quality in small historical centers.
- The manufacturing settlement system prioritizes the concentration of supply in new areas and promotes the reuse of disused buildings. It defines Productive Areas of Metropolitan Interest and supports initiatives for neighborhood and medium-sized retail establishments. Additionally, it encourages the development of interchange and fare integration for the integrated LPT system.

B. General strategic directions for BET

B.1 Orienting urban planning policies toward the energy sustainability of settlements

In light of the scientific debate in section 2.1 regarding urban planning policies that promote energy sustainability of settlements and the findings of this research, the following general policy directions are proposed:

a. Promote **urban densification** and a more compact and polycentric city model to reduce energy consumption (Chapter 2.1).
b. **Polarize primary urban functions** and new development areas about energy networks to promote the use of local and renewable energy sources (Chapter 2.1).
c. Incentivize **functional mix** by encouraging the coexistence of producers and users of renewable and assimilated energy to encourage local renewable energy production and reduce grid losses (Chapter 6.3).
d. Promote the **energy sustainability** of industrial, commercial, and service sector settlements by adopting low-environment impact technologies, using renewable energy sources, and the energy efficiency of buildings (Chapter 7.3).
e. Promote the creation of **energy communities** and forms of aggregation for energy purposes in the territory to encourage citizen participation and the spread of renewable energy at the local level (Chapter 5).

C. Specific strategic directions for BET

The aggregation of information on the scale of territorial homogeneous zones allows for an understanding of the characteristics and peculiarities of each area, thus facilitating better support of local authorities in creating an integrated energy policy.

C.1 Widespread use of RES according to territorial energy vocations

The widespread use of renewable energy sources by the territorial energy vocations of homogeneous areas (shown in Figure 44) can generate numerous environmental and economic advantages. This approach can maximize the return on investment, fostering the development of an economy with a low environmental impact. For example, the analysis of electricity produced in Homogeneous Zones shows that areas surrounding Turin are mainly suitable for solar and, to a minor extent, waste and biogas. In contrast, the foothill areas have a more diverse energy mix, including wind and biomass.

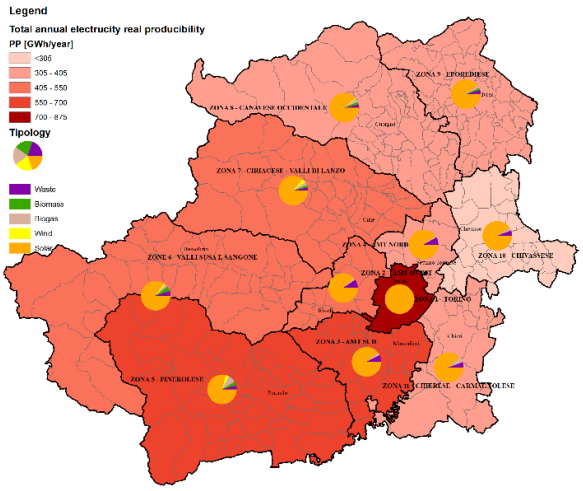
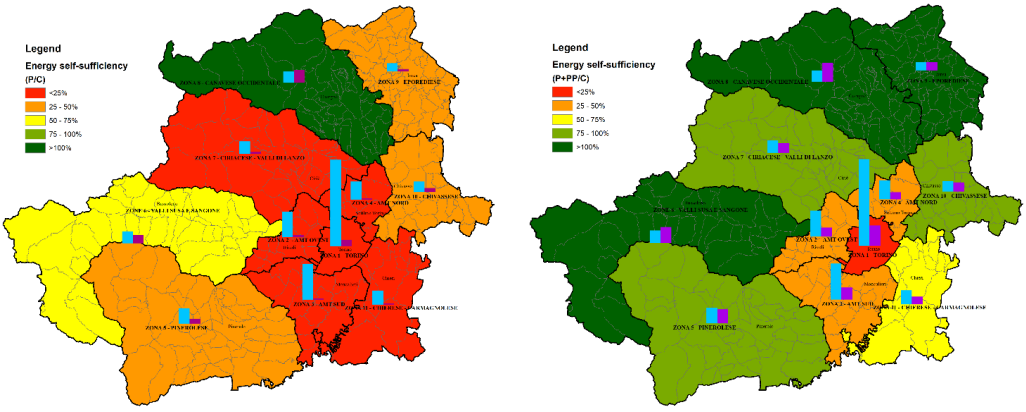


Figure 44: Real electric energy producibility

C.2 Setting priorities and targets based on energy independence of territories

In order to achieve the goal of energy independence of territories, a proposed indicator asses the **degree** of **priority** of **interventions**. This indicator, energy independence (P/C), shows the current situation (Chapter 7.3 and Figure 45a). Meanwhile, to establish **concrete** and **achievable goals** based on the energy basin of the territories, it is possible to refer to the achievable energy independence values (P+PP/C) (Figure 45b). By doing so, we can get a better idea of the order of magnitude and the level of achievement of energy independence for each Homogeneous Zone, making it easier to pursue effective interventions.



(a) (b)

Figure 45: Energy independence of (a) the BAU scenario of existing RES production and (b) the PPmax scenario of maximum production from RES by Homogeneous Zone.

C.3 Specific strategic directions BET

Settlement pattern

The settlement model promotes polycentrism by providing supra-municipal services to major cities. In order to limit land consumption and achieve a scenario of non-dispersed urbanization, municipalities propose delimiting areas by guidelines about dense, vacant, and transitional zones. The perimeter of the areas is a non-binding cognitive and propositional contribution motivated by the Municipality and agreed upon by CMTo and the Piedmont Region. The proposal will be discussed in Co-planning and Evaluation Conferences, and special Conferences of Services under Law 241/90 et seq. may be convened (Table 9).

Table 9: Strategic guidelines for energy sustainability urban texture.

Articles 20, 21 of the Scheme NdA	**Definition**	**Normative effects**	**Example of strategic guidelines for energy sustainability proposal**
DENSE AREAS	Consolidated building texture	• Transformation • Reuse • Urban redevelopment, building replacement, • Densification and completion	- Implement **interventions to reduce the consumption** of the building stock to achive a jump of energy coefficients in each intervention. - Install RES systems as much as possible **integrated** into the building environment.
TRANSITION AREAS	Territory of limited extent on the margins of dense areas and contiguous to them	• Limited settlement increase: -building replacement - densification - completion of enclosed lots	- Prioritize **new energy-efficient building stock** and building replacement of the most energy-intensive buildings. - Install RES systems with the goal of **energy self-sufficiency** and, where possible, **overproduction** with a perspective of transferring to dense areas.
OPEN AREAS	Territory outside the consolidated building and urban texture or built-up areas	• Not usable for new settlements	- As these are the areas with the highest vocation for energy production from RES, verify the possibility of exploitation of environmental resources for energy purposes (by what has been identified by the RES constraints map - E) to maximize their utilization.

Strategic guidelines for the energy sustainability of industrial, commercial and service sector settlements

Productive Areas of Metropolitan Interest (APIMs) are contexts with a high manufacturing vocation or characterized by significant manufacturing presence. In agreement with the Guidelines for Ecologically Equipped Productive Areas (APEAs), a common infrastructure is included in classic industrial infrastructure to improve the environmental and energy efficiency of the area. Companies could benefit from exchanging and using secondary products, saving on the cost of raw materials, such as energy, and promoting collaboration among businesses. However, since only around 10% of the building stock uses 85% of the total electricity in the CMTo, it is essential to focus on these priority buildings to improve the energy efficiency of the entire area (Figure 22).

Moreover, the **Energy Manager** (established by Law No. 10/91) is critical in promoting energy savings and renewable sources. Energy saving, efficiency, and renewable sources also help to **acquire know-how** and **competitive advantages** in the new markets. Therefore, promoting initiatives that attract investment in local production units is essential, stimulating development and employment. However, to achieve these goals, improving access to information and developing a local system that can offer quality services and stimulate demand is necessary.

Energy vector transition policies

Encourage electrification of heating systems through incentive programs and tax breaks (given the widespread use of gas/methane 74% as an energy vector). These programs may include incentives for purchasing heat pumps and electric heat exchangers, electrification of industrial and residential processes, installation of solar panels, and electricity storage (Figure 22).

Information and monitoring activities

In order to encourage the promotion of energy policies, establishing an energy desk must be planned. This energy desk will answer citizens' questions about energy issues and inform local governments about available incentives, such as calls, funds, and vertical incentives. In addition, local governments should target their projects consistent with the directions of the energy plan to contextualize them and maximize the impact of promoted policies.

Activating additional resources over and above the budget allocations will be essential to ensure the effectiveness of the promoted policies. Therefore, efforts should focus on intercepting European, governmental, and regional funding and private investments by the modalities and timelines the promoting entities provide.

Development of local community-based solutions

Developing local energy solutions can stimulate the creation of energy communities and directly involve local communities. The supra-municipal scale (as seen in Chapter 4.5) is the most suitable to achieve this goal. Current regulations (High voltage reference) represent the territorial reference for creating ECs (Figure 21). At this stage, it is necessary to identify EC developers and operators to oversee the preparation of the technical and economic feasibility studies and to involve other interested users.

D. Guidelines and directives for the integration of the energy variable in municipal urban planning tools

PRG

The PRG must specify and deepen the framework of knowledge of the energy image of the belonging BET, integrating new analysis into the urban plan. Specifically, the PRG must:

- Calculate the municipality's current and future **energy demand** and **supply** (municipal energy balance), defining the municipality's **current situation** (P/C) and **achievable energy independence** target (P+PP/C) (Figure 38). By prioritizing actions based on this information, we can establish specific and realistic targets for the municipality.
- **Georeferencing** electric and gas energy consumption (SIATEL database) in the municipal territory and identifying the types (domestic, second homes, non-domestic) of energy consumption (and related particularly critical areas).
- Analyze **spatial variables** related to energy consumption for different parts of the urbanized territory (Chapter 7.2 variable analysis at a more detailed scale, e.g., census sections).
- Georeference existing and planned **energy facilities** and **networks** to assess vulnerability on municipal territory.

- Implement **tools** and **resources** to enhance community action and integrate community into planning frameworks (Chapter 11.2).

RUE

Urban Building Regulations need to incorporate energy performance criteria for the built environment. These criteria should comply with the voluntary requirements for buildings outlined in D.C.R. No. 247-4585, dated November 28, 2017. The new regional standard building regulation (RET) replaces the building regulation approved by D.C.R. No. 548-9691 dated July 29, 1999. The most recent Guidelines define the revision of the Building Regulations for municipalities at the regional scale, providing general principles and uniform definitions. This tool is effective in achieving distributed change at the territorial level. However, it needs to define generalized technical-operational contents suitable for the various local and territorial contexts.

In defining the regulation of transformation interventions, the RUE indicates the measures to be applied to encourage installing systems to produce energy from renewable sources and constructing energy-efficient buildings. The RUE also contains the definition of urban-energy indexes and parameters and the methodologies for their calculation. The **Bologna Building Regulations** are a great example when creating a RUE. This document has a unique approach as it emphasizes performance more by setting objectives without limiting engineers' freedom to find a solution to meet the desired result.

VAS

Using simulation models, the energy impacts of planned settlements and any energy retrofit policies should also be verified during the Environmental and Territorial Sustainability Assessment (VAS). The PTGM should provide benchmark *P/C* and *P+P/C* indicators to measure the energy performance of the urban plan.

D.1 Directives on the energy sustainability of settlements

- Provisions for urban "densification": introduce a system of building indices and typological abacuses consistent with increasing urban density and compactness of settlements, regulation of form, building types, densities, and functional mixes.

- Provisions regarding the energy sustainability of industrial settlements, functional clusters, and commercial and tertiary settlements: identify areas suitable for establishing production activities classified as high energy intensity provision for a share of the settlement's energy needs using RES about the vocational area. The location criterion is consistent with the connection to district heating networks.

E. Mapping criteria for the location of RES plants - Environmental, technical, and prescriptive regulatory constraints

In order to make spatial constraints that limit the utilization of renewable energy sources understandable, the following section presents current regulatory constraints. This section provides a **prescriptive map** indicating where different types of renewable energy production plants can be located within the territory, making obtaining permits easier and streamlining the process.

The Piedmont regional resolutions, DGR 3-1183/2010 and DGR 53314/2012 (reconfirmed with the new PEAR of 15/03/2022) define areas unsuitable for renewable energy production plants. These areas can be categorized into four types:

1. Areas restricted for protecting landscape, historical, artistic, and cultural heritage.
2. Areas with significant consideration for the environment, air quality, and protected areas.
3. Agricultural areas of significant value and importance.
4. Forested areas, and areas subject to hydraulic and hydrogeological hazards.

Unsuitable areas and attention areas for the location of wind power plants

The criteria aimed at identifying areas unsuitable for the construction of wind-powered power plants focus mainly on issues related to the visual fruition of the landscape, as well as the impact on avifauna/chiropteran fauna, as also provided in the cited point 17 of the Guidelines, and generate limitations according to the plant sizes (Figure 46):

- 0 kW < plant size < 20 kW, micro wind for self-consumption
- 20 kW < plant size < 60 kW, micro wind power
- 60 kW < plant size < 200 kW, small wind power
- plant size > 200 kW, industrial

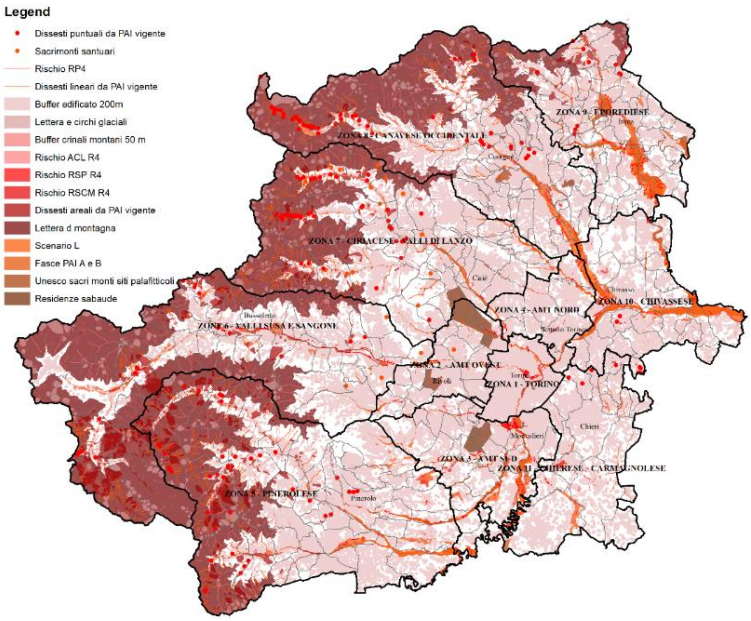


Figure 46: Unsuitable areas and attention areas for the location of wind power plants.

Unsuitable areas and attention areas for the location of biomass-fueled power plants

In accordance with the Ministerial Decree of 09/10/2010, by its own Resolution No. 6-3315 of 01/30/2012, the Regional Council selected the following sites and areas as unsuitable for the installation and operation of power generation plants fueled by biogas and biomass from lignocellulosic and liquid biofuels supply chains (Figure 47):

1. Areas under protection of landscape and historical, artistic and cultural heritage.
2. Environment and protected areas.
3. Agricultural areas.
4. Forest areas and areas under hydraulic and hydrogeological instability.

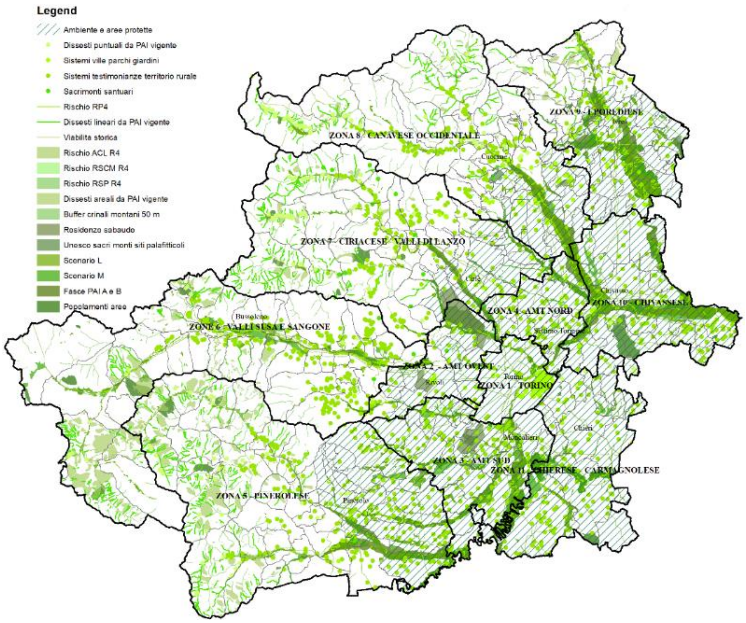


Figure 47: Unsuitable areas and areas of attention for the location of biomass-fueled power plants.

Unsuitable areas and areas of attention for the location of hydropower plants

The criteria aimed at the identification of areas unsuitable for the construction of hydropower plants focus mainly on the quality of water bodies with reference to the areas of the Natura 2000 network, as also stipulated in the cited point 17 of the Guidelines.

Since the preliminary investigation was conducted, the following sites and areas have been identified as unsuitable for the installation and operation of plants to produce electricity powered by the hydraulic source (Figure 48).

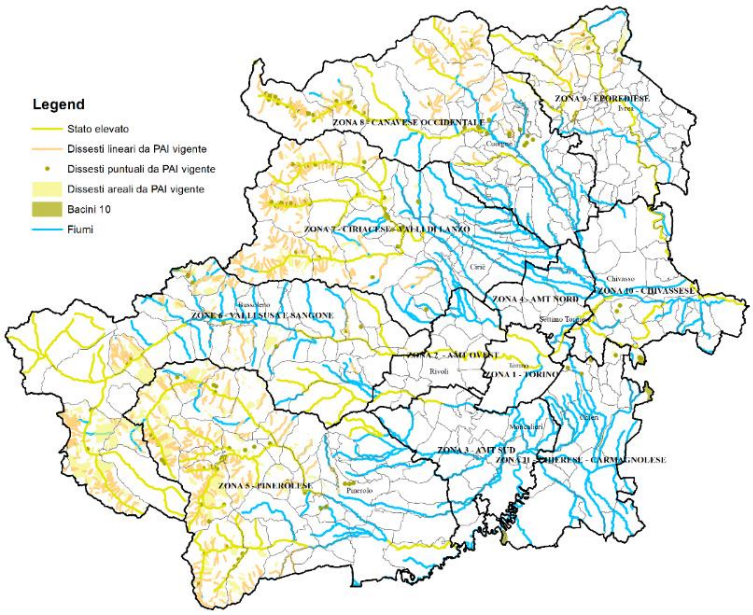


Figure 48: Unsuitable areas and areas of attention for the location of hydropower plants.

F. Vade mecum for community energy projects

This paragraph aim to extrapolate and summarize from the analysis of energy cooperation in Denmark several **elements** and **actions** to be taken to start successful processes in the Italian context.

The role of local and regional governments in promoting renewable energy is recognised by the Renewables Directive, which highlights that local governments have the opportunity and responsibility to use their powers to introduce binding regulations that support the development of community energy (Roberts et al., 2014):

- At the regional level, setting up non-binding strategic policy goals or targets.
- At the local level, integration of community energy into local regulatory frameworks by implementing land use planning actions or regulations, such as building standards, and setting long-term goals and strategies.
- At the municipal level, public tenders to guide the purchase and consumption of electricity from renewable sources. When evaluating offers, social and economic factors should also be considered, rather than just the lowest price offered.

Local governments should focus on **implementing tools** and **resources** to improve community action and **integrate community power into planning frameworks** and streamlined permitting procedures (Reescoop.eu).

i. **Guidelines and other technical and informational supports**. Such as guidance that specifies how local authorities should support local communities in developing renewable energy.
ii. **Guidance for citizens and community organizations** and businesses to make local legal frameworks easier to navigate. Such as developing a wide range of information for community groups interested in starting a community energy project.
iii. Fostering the emergence of **intermediaries** that broker relationships between community members, investors, and institutional bodies (T. Hargreaves et al. 2013, C. Bird, J. Barnes 2014, and K. Sperling 2017).

It is essential to integrate community energy into planning frameworks and simplify permitting procedures. Some strategies to be employed along with examples of their application are listed below:

- **Integration of community energy into land use planning frameworks**: In Denmark, where land-use planning is managed at the local level, the municipal plan should include guidelines and a framework for areas chosen for the installation of wind turbines, specifying the maximum expected number, size, and spacing between turbines.
- **Integration of community energy into urban planning requirements**: Typically, urban planning regulations require the installation of solar PV or thermal systems in new buildings and during the renovation of existing buildings. In Denmark, municipalities must consider heat planning in their land-use plans, assessing whether buildings should be connected to the heating grid and may impose a requirement to do so.
- **Simplified permitting procedures for community energy projects**: Environmental impact assessment (EIA) is a particularly important consideration for community energy projects, as it can be costly and time-consuming. In Denmark, planning is often done in collaboration between the project owners and the municipality. Some examples of simplified permitting procedures include:

a. Gradual scaling of requirements: Reduce the requirements needed to obtain a permit according to the size of the project.
b. Automatic authorization: For exceedingly small projects, there is often a deemed authorization system, where an individual application is not needed.
c. Notification: The law applies to models that have already been certified and safety tested. In this case, it may be sufficient to notify the municipality as a semi-permitted form of development. If the council raises no objections, the development can go ahead.

Chapter 12

Solutions identified for overcoming energy planning barriers

This chapter addresses the solutions for overcoming energy planning barriers in the Italian context toward the **Urban Energy Plan**: characterizing elements and directions in the disciplinary debate (De Ioris, 2014).

In recent years, research in this area has slowed, if not stopped. The main difficulties are related to operational factors that make urban planning a field with low permeability to innovation. The separation of energy and planning combines with an Italian tradition of sectoral planning by thematic area disconnected from the overall plan.

New methods and **procedures** of spatial planning are needed, as well as the development and application of new tools to move from the building scale to the territorial scale (Zanon & Verones, 2013). A profound **restyling** in the architecture and methodological approach of ordinary planning instrumentation makes the spatial government process more permeable to the energy component.

The proposal aims to integrate energy and spatial planning by focusing on some critical elements of the plan, as highlighted in the literature review (De Pascoli et al., 2014; De Pascali & Bagaini, 2019) and the comparison of selected case studies (Part III) on Urban Energy Plans (Chapter 4.5). The proposal goes into the topic, adding new elements and insights from the application case study. The Urban Energy Plan incorporates energy valence into the planning process, considering the methodological (formation and management) and structural level (planning constraints). The following critical elements are applied and will be explored in detail regarding the case study:

1. The **conforming territorial dimension** of the plan is the **vast area**, which is the most suitable for capturing the different aspects of the energy variable.
2. The **reference spatial partitions** are essential for guiding plan choices and result from interactions between the two disciplinary contributions.
3. **Integrating** the **energy component** into all stages of the planning process, from analysis of needs to evaluation of results, is essential. This integration is through the spatial planning strategy of a **mainstreaming approach** to energy resilience.
4. The **public-private relationship** plays a vital role in this process. Active involvement of citizens and businesses can help achieve goals and ensure that we use renewable sources best. For this reason, Energy Communities appears as an interesting opportunity.

In conclusion, this research discusses the need to integrate energy and spatial planning in the Italian context and further the research debate by proposing innovative spatial planning methods and procedures. The Urban Energy Plan's four characterizing elements are discussed in more detail concerning the proposal of the energy-driven meta-plan (Chapter 12).

12.1 Conforming territorial dimension

The spatial scale on which to operate represents an aspect that needs adequate attention. In literature (De Ioris, 2014; Alagna et al., 2021; De Pascali & Bagaini, 2019), it has emerged that it is in the **vast area** that attention also needs to be focused in terms of research.

Vast-scale analysis corresponds to the metropolitan city scale. The proposed meta-plan analyzes Turin's Metropolitan General Plan (PTGM). This experimentation stimulates discussion and activates attention to the "energy and territory" relationship.

The perception of energy impacts at a larger scale is challenging to compare with those of a single building. This difference is because the results are immediately tangible and direct; conversely, the larger the scale, the more difficult it will be to assess a change. In general, tools like the RUE, which act on individual buildings, are more developed and better suited for experimentation and obtaining approval from private operators who benefit from the set incentives. However, using such instruments can activate reward systems, which in turn may cause a

delay in the integration process between energy and land use planning (Chapter 4.5).

Achieving goals in the territorial context requires strategies that transcend the limits of local government. The scale of the municipality is different from the appropriate scale to govern larger-scale processes (Veronese & Zanon, 2013). The vast or supra-municipal scale well **intercepts** the **energy dynamics** of territories. We have seen the link between energy and territorial characteristics: geomorphological, infrastructural, organizational/managerial, and socio-economic (Chapter 7.3). Another element highlighted is related to the electricity distribution network. As seen above (Chapter 7.4), the spatial reference for the creation of RECs is the high-voltage substations, which design RECs through the aggregation of municipalities.

The vast area scale is ideal for **acting somewhere between** the greater operationality of the municipal scale and the generic guidelines of the regional scale. It succeeds in defining **development strategies** based on the characteristics of the aggregations. The supra-municipal scale integrates objectives and strategic actions to achieve energy sustainability objectives related to the territories' specific needs. The groups of municipalities represent a proper context in the definition of these adaptation processes, as the impacts of climate change often involve broader territorial contexts than the individual municipalities.

12.2 Reference spatial partitions

The reference spatial partition brings the integration of energy and spatial planning to the basis of the structural guiding element in producing the comprehensive plan. Integrating the two subjects must go through a **definition** of a **spatial partition** and an overall organizational design. Therefore, it is necessary to define an appropriate spatial partition to balance the different elements of the territory, characterized by its complexity.

The absolute particularity is in the definition of the **hybrid intervention units**, to use them as the basis for building **plan strategies**. In work, we sow an example of the application of energy district (the BEU of Bologna) and an example of the energy basin (the BET of Modena). While energy districts present a series of limits (Chapter 10.1), the theme of the **energy basin** in the territorial plan is fundamental to investigate. The BET for is characteristics is applied at a vast area scale and is, therefore, a direct consequence of the choice of scale seen in the previous point.

The plan proposal uses the Territorial Energy Basin to realize energy conservation and RES promotion at a vast scale. According to Law 10/91 and the manualistic studies that followed it, defining a basin means identifying users' characteristics, size, needs, and energy demands and outlining economic issues.

Local governments, therefore, must identify the most appropriate territorial partition starting from a collimation of energy supply and demand. Since each territory has its peculiarities, partitions cannot be predetermined, let alone standardized, but somewhat flexible and linked to the intrinsic characteristics of territories dictated in the first instance by the development potential that local resources can offer.

According to these assumptions, the proposed plan, following what began with PRODEM (2006), starts describing and optimizing the territory according to its energy vocation. In the work, BETs are, as an example, fixed as homogeneous territorial areas of PTGM, on which structure the energy planning strategies. In this way, in addition to a descriptive-interpretive function of the relations between energy and territory, they assume a programmatic role: regulatory addresses in the energy field.

Energy basins, despite their vague and uncertain definition, show great potential. They are trying to explore this topic and add new elements and insights from the application case study. The result of the proposed plan outlines the characteristics the reference spatial partition should possess to align with the energy component.

- Energy and spatial **macro-indicators** should guide aggregation (e.g., SCI and SSI). Then, the regular planning process could gradually incorporate them.
- Pre-existing forms of aggregation defined by territorial planning should be evaluated to **homogenize** the **aggregation** and **organization** of municipalities (e.g., Territorial Homogeneous Zones). These pre-existing forms will ensure consistency and address the most relevant plan at a large scale.
- A relevant **energy actor** and **intermediaries** in the territory should be identified (e.g., the ACEA entity deals with energy distribution, production, and citizen involvement initiatives in the Pinerolese area). This entity is crucial as a **link** between the various actors that come into play and as a point of reference.

- The presence of primary substations (High Voltage cabins) may be a relevant element in choosing **territorial aggregations**. The reason is that Renewable Energy Communities allow the creation of community projects that refer to this spatial element.

The best way to approach the reference spatial partition is to keep the **definition open-ended** and **flexible**. This loose definition creates a broad concept that can be adjusted to suit the context under analysis. It is optional to arrive at a commonly accepted definition; instead, utilize a **hybrid aggregation** that prioritizes specific characteristics. The proposal presents data collected and measured at the municipal level, leaving it open to aggregate at a supra-municipal level. Technology, such as the presented platform, facilitates dynamic aggregation evaluations and enables the creation of scenarios based on calculated data by aggregating municipalities using different methods (Appendix A).

12.3 Integrating the Energy Component

The mainstreaming approach is a spatial planning **strategy** that integrates specific issues within spatial policies and programs. The mainstreaming approach aims to **integrate** specific issues **into all stages** of the **planning process**, from analysis of needs to evaluation of results, ensuring that they are not dealt with separately. In particular, the mainstreaming approach to adaptation for energy resilience aims to integrate climate change adaptation and energy resilience issues into all energy planning and management aspects, from supply to distribution and final use (Brunetta et al., 2021).

The 2015 Paris Agreement is one of the landmark documents highlighting the importance of this approach. Then the Intergovernmental Panel on Climate Change (IPCC) Report on limiting global warming to 1.5°C and the United Nations 2030 Agenda for Sustainable Development, which includes Goal 7 on access to clean and reliable energy, are essential documents on this topic.

The meta-plan proposal adopts the **mainstreaming** adaptation approach for **energy resilience** (Chapter 12), introducing measures and actions for transition, adaptation, efficiency, and *green* conversion of networks in the ordinary instruments of territorial and urban planning (EU, 2021). Energy planning could better meet the needs of governing districts and homogeneous morphological and settlement areas, prefiguring new strategies for the ecological transition of the territories (Doost et al., 2020).

This essay emphasizes the importance of territorial planning for energy resilience, which involves the development of sustainable models of natural and human resources within local communities (Brunetta et al., 2019). This approach requires a **multi-objective** and **multi-sectoral strategy** to bring energy and spatial planning closer. The mainstreaming approach perfectly matches the choices of the vast area as the plan's conforming territorial dimension. This matches because it operates between the greater operationality of the municipal scale and the generic guidelines of the regional scale. For this reason, the proposal integrates with the plan of the Metropolitan City and applies the same level of cogency. The integration result of the energy issue appears homogeneous, and the plan respects its consistency.

12.4 Public-private relationships

The public-private relationship and the role of citizens, companies, and local governments characterize the proposed plan. Active involvement from these parties is crucial to achieving the economic, social, and environmental goals related to using renewable energy sources (Rescoop.eu). Citizen-driven bottom-up initiatives are driven by several factors: political support (Danielsen, 1995; Kemp et al., 2001; Jørgensen & Karnøe, 1995), financial support (Olesen et al., 2004; Bolinger, 2005), and cultural factors (Bolinger, 2001). However, growing local opposition to installing new renewable energy facilities poses a significant risk to stopping new projects. This opposition stems from aesthetical objections, objections to specific decision-making, and the distribution of economic benefits (Jobert et al., 2007 in Chapter 11.2.3).

To address these challenges, **Energy Communities** represent a new model of public-private collaboration to guide ecological transition. These community models discuss the characteristic elements and ways of activating community energy projects, considering the role of citizens, companies, and local governments. By involving public and private actors equally and actively, energy communities enable the achievement of economic, social, and environmental goals related to using renewable sources. Thus, energy communities represent a new model of horizontal cooperation aimed at pursuing the goal of ecological transition (Chapter 5).

The Italian context currently needs to be more collaborative in the energy business, with a significant gap of 35 ECs when compared to more successful European states such as Germany (1750 ECs) and Denmark (700 ECs) (RSE, 2022).

It is essential to involve citizens to avoid hindrances to the energy transition caused by NIMBY processes. Local institutions should take **proactive** and independent measures to **facilitate** the **participation** of energy players in energy communities (Roberts et al., 2014).

The proposal suggests a vade mecum for community energy projects (Chapter 12.2.2) to achieve successful processes, which includes crucial elements and actions to get started. Local governments should focus on implementing tools and resources to improve community action and integrate community power into planning frameworks and streamlined permitting procedures. Moreover, it is essential to integrate community energy into planning frameworks and simplify permitting procedures.

12.5 Future research

Pillars for Energy Plan

Energy planning is a crucial aspect of territorial management. The proposed next-generation Energy Plan addresses this issue by emphasizing **four foundational pillars**. As highlighted in the relevant bibliography, these core characteristics must be the primary focus when developing a plan that integrates energy issues with spatial planning concerns. The four pillars are conforming territorial dimension, reference territorial partitions, integrating energy into the plan, and fostering public-private relationships. The plan proposal integrates energy and spatial planning by focusing on these pillars, going into them, and trying to add new elements and insights from the application case study.

The following step to advance the research is to move from Meta-Planning to a Planning level (Moroni et al., 2023), which requires **specific** and **concrete actions**. These actions align with the four pillars of the Urban Energy Plan, which are as follows:

1. Integrate the Vast Area Plan with the Urban Energy Plan using the same plan coherence as complete text regulations (Chapters 12.2).
2. Define a hybrid reference spatial partition as a guiding structural element to implement specific strategies based on the territories' characteristics and social relevance (Chapter 12.1).
3. Introduce measures and actions for transition, adaptation, efficiency, and green conversion in the ordinary territorial and urban planning instruments through multiple plan objectives that consider and deal with

the environment, urban settlement, society, and energy (e.g., measures B, C, and D in Chapter 12.2.2).

4. Identify key territorial energy actors, such as local institutions, energy actors, and intermediaries, and charge them with implementing tools and resources to improve community action and integrate community power into planning frameworks and streamlined permitting procedures (e.g., measures F in Chapter 12.2.2).

Moreover, to ensure the plan's effectiveness, the following **supporting conditions** must be researched and applied:

- Place the energy parameter alongside ordinary planning tools such as self-consumption and self-sufficiency index (Chapter 12.2.2).
- Schedule interventions according to energy scenarios using a place-based methodology to evaluate information such as the Maximum RES Producibility (Chapter 7.4.4).
- Implement tools and procedures for monitoring interventions to evaluate the plan's effectiveness, such as a spatial energy platform (e.g., Appendix A).

The practical application of the plan will provide opportunities and challenges, leading to a fresh perspective on the subject matter.

Community energy projects

Energy Communities present a significant opportunity for guiding and accelerating the energy transition in territories. As a result, their planning and management are crucial for energy and spatial planning. By offering a solution for energy security and access to clean energy, Energy Communities can enhance the integration of energy and spatial planning to address current urban challenges.

The **integration** of community energy projects into **spatial planning frameworks** is a crucial research area that requires focus. The practical implementation of integrated community involvement and participation procedures in spatial planning is the next step in this research. To successfully incorporate community energy into planning frameworks and streamline permitting processes, it is essential to prioritize research on critical components, as exemplified by Denmark's successful approach (Chapter 11.2.3). This involves integrating community energy into **land-use planning frameworks**, such as establishing guidelines for renewable energy systems in local plans. Additionally, incorporating community energy into **urban planning requirements**, such as mandating solar

systems in new and renovated buildings, is crucial. Finally, **simplifying permitting procedures** for community energy projects through gradual requirements scaling, automatic authorization, and notification can further support the integration of community energy into planning frameworks. This implementation will enable the exploration of new permitting procedures solutions, which can be adapted to different places and contexts of application. Moreover, the future of research in energy exchanges and managing grid complexity holds the potential for creating a sustainable and resilient energy system. The critical focus areas are **establishing national** and **European networks** for energy exchanges and **managing grid complexity** in the face of increasing renewable energy production.

At the national level, the recent REC Decree Dm 414 of 2023 regulates, by DLgs 199 of 2021, the incentives for electricity produced by renewable energy plants in self-consumption configurations. This Decree closes the experimental phase and starts the final implementation of collective self-consumption forms. The measure aims to encourage the development of 5 gigawatts of renewable energy production facilities by 2027, starting **crucial economic** and **legislative support** for the coming years.

Implementing a robust and interconnected national/European network for energy exchanges involves harmonized regulatory frameworks, exploring innovative policy mechanisms, and international agreements. Managing grid complexity can be addressed by developing advanced management techniques, integrating energy storage systems, encouraging demand response programs, and enhancing grid resilience through redundancy measures and intelligent fault detection.

Chapter 13

Conclusions

13.1 Outcomes

The issues raised in Chapter 1 were identified in the following points, divided in policy and technical issues. From the policy side literature highlighted:

- Lack of integration of energy strategies into spatial planning (Balducci, 1991; Mazza, 2004, Zanon & Verones, 2013)
- General absence of a strategic dimension (Brunetta et al., 2020).

From the technical side literature highlighted:

- Lack of spatial dimension of energy data (Stoeglehner et al., 2016)
- Low technical knowledge and expertise with regulation constraints of the local authorities (Lombardi et al., 2010).

Theoretical and methodological contribution identified as a solution to overcame these spatial energy barriers are:

1. **Restyling ordinary planning tools** to guide territory considering energy aspects - policy side.
2. Identification of **tools** and **methodologies** for the spatialization of energy to guide decisions in the energy-related policies - technical side.

In summary, the work improve solutions to **integrate energy strategies** into the spatial planning process from policy and technical point of view.

13.2 Advancement of the dissertation work

This section outlines the advancement of the dissertation work as results of the energy metaplan proposal. The proposal presented in the case study of the Metropolitan City of Turin seeks to make progress by highlighting the following

developments. The work shows improvements related to integrating technical evaluation aspects into spatial planning tools to enhance knowledge and decision-making processes:

- The proposal introduces a new **methodological level** to evaluate the **effective energy production** from renewable sources. This element allows us to consider this fundamental element during the plan's implementation. Scheduling of interventions according to **energy scenarios** (definition of quantitative development of the area). The work evaluates Business As Usual and maximum producibility scenarios, which help define achievable spatial strategies.
- The proposal introduces **energy flow profiling** (demand and production) during different time steps, highlighting the importance of considering the time dimension when RES sources and ECs are involved.
- The proposal introduces defining and evaluating **spatial energy indicators** (SCI and SSI). These energy parameters should be combined with **ordinary planning tools** to help the decision-making and monitoring process.

From the other side, the work shows improvements in improving the planning approach:

- The proposal introduces a **restyling** of the PTGM of Turin following four main pillars. The metaplan proposal plans spatial-energy strategies to enhance multilevel coordination among public authorities that fits the PTGM cogency plan.
- The proposal introduces **hybrid** and **dynamic aggregation** at a vast scale according to spatial needs. In the work, BETs are, as an example, fixed as homogeneous territorial areas of PTGM, on which structure the energy planning strategies. However, the best way to approach the reference spatial partition is to keep the **definition open-ended** and **flexible**.
- The proposal introduces improvements to the **participation phase**. By implementing a vade mecum for community energy projects (through a qualitative method), this work intends to set functional elements and actions as best practices to follow.

13.3 Planning policy implications

The proposed planning approach imply a series of **operational interventions**. In fact, it is necessary to intervene at the local scale (integration of the PRG, VAS, RUE) according to the strategic directions of the vast scale. For this reason, the analyzes and tools proposed help decision makers in this sense, offering data and procedures to follow. Furthermore, it will be necessary to allow citizens to be an **integral part** of the **project**, by owning and investing in plants and for efficiency interventions. The object is to making them part of the strategic directions of the project and aware of the benefits and impacts on society. Land use can improve people's perceptions through public-private agreements. For example, negotiate agreements with landowners ensure receive support to obtain a RES plant on the condition that they would offer a share of the purchase to the community (e.g., Samso). This helps to foster cooperation and minimize potential conflicts.

A solution to better manage these two dynamics - the need to define operational interventions on a local scale and make citizens an integral part of the projects - could be to **establish** an **institute** responsible for the topic. This institute will have to deal with relations with the population and support in implementing tools and resources to improve community action, integrate community power into planning frameworks, and streamline permitting procedures. This institute serves as a mediation and information office, acting as a bridge between different stakeholders, easing communication and ensuring the consideration of the interests of all parties.

13.4 Conditions for the exportability of the planning approach

This paragraph identify the conditions for the exportability of the proposed planning approach, partly already mentioned, from the analysis of energy cooperation in Denmark and the national good practices. The methodology used is replicable in other context and with different data sources. While the planning approach present some starting conditions to be applied.

The role of local and regional governments in promoting renewable energy is recognised in the Emilia Romagna good practices, which highlights that local governments have the **opportunity** and **responsibility** to support the **integration** of energy into spatial planning:

- At the regional level (the Regional Urban Planning Law 20/2000 and the Territorial Energy Planning Law 26/2004), setting up strategic policy goals or targets.
- At the local level (the PRODEM research, a new methodological approach), integration of energy into spatial planning frameworks by implementing land use planning actions and regulations.
- At the municipal level (the PEC of Bologna), specifying and deepen the framework of knowledge of the energy image, integrating new analysis into the urban plan.

The results coming from the analysis of Denmark highlights that culture, familiarity with cooperation, and shared ideologies, are the **starting conditions** of the citizenship necessary for engage a **community energy projects**. A competent social actors should be find to guide the collective action. Then, the state must long-term political and financial support. Indeed, critical factors for developing local energy ownership models:

- Stable policies and political support for renewable energy and the energy transition
- Targeted promotion of local energy communities

Therefore, a critical condition is that the public administration must be **proactive** and take responsibility and opportunities at the various levels. The state must ensure stable policies over time and set general direction, which must be declined at the regional and vast scale and find application at the municipal level. At the local scale, the citizenship must be informed and involved in decision-making to make projects succeed.

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RSE atlante eolico: https://atlanteeolico.rse-web.it/start.phtml

Renewable Energy First site:
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Appendix A - Platform for improving the supply and demand collimation

The Renewable Energy Community is not just an initiative between private entities; public entities like municipalities and other territorial public bodies can play a crucial role in territorial energy planning and REC governance. Therefore, a governance model based on the specific characteristics of each territory is needed to ensure that the REC effectively benefits its members and contributes to the territory's sustainability and resilience. A digital energy platform can help manage the complexity of data and facilitate the identification of optimal aggregations of energy end-users and local renewable energy sources. This Platform can support decision-makers in two areas: planning and management. **Strategic planning** is essential for assessing the effects of implemented energy policies, defining new objectives, and coordinating actions to increase sustainability and quality of life. **Management** includes data monitoring, plant maintenance, and economic reporting. It could also involve the realization of hardware or software infrastructures, optimizing economic and human resources, and developing local supply chains and networks of sharing services to promote local economic and employment growth.

Methodology

The digital energy platform is a decision-making tool that helps define local energy policies. It comprises energy consumption and production models describing current and potential development scenarios. The Platform integrates energy planning models and REC technical-economic feasibility studies with a complex system of indicators to assess the effectiveness of implemented actions and monitor the overall degree of territorial sustainability against established objectives. The Platform takes a holistic approach to consider technical, socio-economic, and regulatory constraints and opportunities and a place-based approach

to highlight local peculiarities and include a spatial component in any evaluation at different scales.

The general architecture of the Platform **integrates energy analyses** and evaluation systems through indicators (Chapter 6 and 7). The energy profiles of consumption, production, and productivity are defined based on the source and time scale of the input data. The accuracy of the results depends on the latter because energy and economic analyses necessarily take place in hourly detail. Depending on the time scale of input data, energy models are used to bring the data back to the hourly level, considering different types of end-users and available renewable energy sources.

The use of GIS systems for spatializing data allows for representing the results of any energy simulation according to different degrees of output data aggregation both temporally (hour, day, month, year) and spatially (single user, REC, municipality, territory). Combinations of energy profiles constitute scenarios that can be compared through the spatial representation of the Platform and evaluated regarding performance indicators.

The work defines a framework of an energy platform to support the management of energy communities. In particular, the following chapter analyzes the platform interface's result to describe its functionalities.

Results and conclusions

The platform proposed in this study is supported by a database that utilizes energy models at a large scale (Chapter 6 and 7). It can help decision-makers **identify effective energy policies** by considering the surrounding characteristics, such as buildings, the socio-economic conditions of the population, and climatic conditions. The platform also allows for an **easy-to-consult energy atlas** based on current territorial databases. It can **assess the feasibility of establishing energy communities** by aggregating private and public entities based on their energy consumption and production.

The framework proposed in this study uses a GIS-based solution to manage energy communities at different territorial scales. It provides an upgradable energy atlas related to existing territorial databases and methodologies to evaluate the feasibility of reaching energy security with low environmental impact and socio-economic benefits. These interdisciplinary assessments encourage territorial stakeholders to participate in the energy transition process.

The study shows that energy self-sufficiency and self-consumption indicators are measurable and can be associated with quality thresholds. The platform visualizes these indicators at different scales, helping users understand how to improve energy performance and identify effective energy policies based on the characteristics of the territories.

The platform interface (as shown in Figure 49) was built with the help of technical specialists through programming languages in order to build a Web-GIS page. This evaluation makes it possible to create **dynamic aggregations**, a solution that fits with the concept of Territorial Energy Basins. The platform can evaluate dynamic aggregations of municipalities, assume different **scenarios,** and obtain values of production, consumption, and indicators such as self-sufficiency and self-consumption at different time steps (annual, monthly, hourly).

Once the selection has been set, the results show the energy balance at different time steps. By calculating energy indicators with different details, policymakers can monitor how other territorial aspects vary as energy conditions change. Therefore, it is possible to observe the best combinations of users and renewable energy sources according to the territorial and temporal scale considered. This decision support tool can help territorial stakeholders better orientate energy policies concerning RECs and monitor the territory's quality indicators.

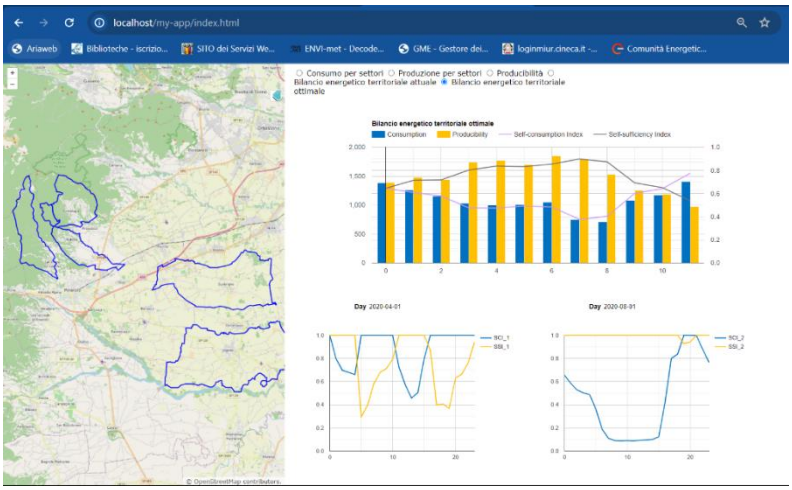

Figure 49: Platform interface showing the results of energy indicators (SSI, SCI) at annual and hourly time scale on a selected day, scenario of a REC with selected municipality indicated on the map.

Appendix B – Questionnaire

1. **Form/model of local energy cooperation**

- What **form/model of local energy cooperation** has been activated? (e.g., community-led investments, end-user-owned utilities, farmer cooperatives, supply chain initiatives and trade associations)?
  - What is the public-private relationship in general?
  - Who are the promoters and administrators?
  - What is the role of public administration and what is the role of citizens?
  - What other characteristics does it have?
  - Are technical skills involved? In what way?
- What are the **drivers** that guide local energy cooperation?
  - What are the goals/drivers that led to local cooperation?
  - How did this type of cooperation start?
  - How is the territorial/social dimension of cooperation established?
  - Are there fertile (base) elements that drove local cooperation?

2. **Stakeholder and economic management**

- How are these forms/models of cooperation **managed** at the level of **stakeholder involvement**?
  - Are citizens involved?
  - In what ways are citizens involved?
  - How are decisions made?
  - How do citizens participate in policy and decision-making?
  - Is there a process for informing the users? How does it happen? Can platforms/online tools be used?
- How are these forms of cooperation **managed economically**?
  - How are the projects proposal financed?
  - What are the economic and social benefits they provide?
  - How are the economic benefits reallocated?
  - How are financial aspects, such as investor remuneration or cost sharing among cooperation partners, managed?
  - Is a platform used in the evaluation process? If not, could a platform simplify the process and how?

3. **Managing in spatial planning**

- How is this form of cooperation **managed in land use planning**?
  - Do cooperative decisions affect land uses?
  - How are local energy cooperation projects integrated into spatial energy planning?

    Are there conflicts or synergies between local energy cooperation activities and national or regional energy policies?
  - What is the involvement of local institutions in the management of this cooperation?
  - How is the issue of environmental protection and security addressed in this cooperation?
  - What are the main challenges encountered in managing these forms of cooperation in spatial planning?

4. **Technical functioning of the cooperation**

- How are **energy fluxes** and **economic incentives calculated**?
  - Are energy models or actual energy meters used to collect energy data?
  - Is hourly energy data available?
  - Are there difficulties in managing shared energy data emerging?
- What is the **territorial dimension** of the users involved?
  - Are there constraints on participation in energy communities? (e.g., plants > 1MW and primary cabin in Italy)?
- How is **technical-environmental feasibility** evaluated?

  Is compatibility with urban planning and environmental constraints evaluated for the implementation of new RES plants? How?
  - How is the non-programmability of RES generation managed? Are storage technologies used? How is the share of self-consumption optimized?
  - Is any tool used for preliminary assessment and optimization? What are they and how are they used?
- What are the **major constraints** and **technical challenges**?
  - Are there any bureaucratic/technical/cooperation constraints?

Stakeholders

There were four actors interviewed, representative of each case study. These actors were directly involved with the projects and were either part of the

cooperative or part of the municipality. In addition, an experienced private specialist, updated on the latest developments was interviewed. Finally, two experienced researchers on the topic, who are part of Roskield University and the University of Cophenagen, were then interviewed.