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Renewable Energy Communities and Public Private Partnership: The case of Montevarchi

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Introduction

The Covid-19 pandemic and the measures to contain it have undoubtedly left signs of economic, financial and social destabilization. The post-lockdown recovery of productive activities, also driven by the enormous demand caused by the economic availability of increasingly generous monetary policies, has generated inflationary phenomena among advanced economies, which they have not observed for decades. These are then driven above all by the increase in energy prices and more generally in raw materials. In Europe, this is also exacerbated by the recent conflict between Russia and Ukraine and the sanctions applied by EU nations to Russia, on which many European states, including Italy and Germany, are heavily dependent. These phenomena of both a social and natural entity have acted by catalyzing, in the USA, but also in the EU, the regulatory and social process that is heading towards the so-called "Energy Transition". The EU's REDII and the US Inflation Reduction Act are clear examples of the will to undertake this revolution of the economic and production systems that have characterized the models according to which advanced nations produce and consume up to now. The growth trend of the world population and the forecasts of rapid urbanization especially in developing countries have aroused global concern for the need to combine growing energy needs, energy justice and environmental issues. In this macroeconomic context, therefore, the energy communities are inserted, representing one of the tools with which the energy transition will take place. They are essentially the tool through which users can produce energy through small renewable energy plants, such as photovoltaic panels, consume it on-site or share it with other users in their proximity connected to the grid, all these thanks to the application of existing infrastructures and IoT technology that allows the exchange of data and information to optimize energy flows. Among the major benefits that this technology brings with it is energy efficiency, as flows are managed locally and there are drastic reductions in energy losses, the increase and integration of new renewable energy production plants and the improvement of the stability of the grid, all without the need to build new plants which, in developed countries, it would be economically inconvenient to redevelop.
However, the implementation of these initiatives is complex both from an organizational and economic point of view, as they represent a novelty from the perspective of the business models also adopted by ESCos and energy distribution and production companies, the latter strongly oriented towards centralized and programmable energy production systems.

Therefore, following the implementation by Italy of the European Directive REDII, and the allocation of huge resources in favor of the energy transition thanks to the PNRR, this thesis will address the issue of RECs in Italy under the PPP regime. Specifically, through the qualitative analysis methodology of the case study, it will be assessed whether in the first case of REC proposal under the PPP regime of the Municipality of Montevarchi (AR), in Tuscany, it is optimal from the point of view of satisfying the interests of the bearers of interest involved in the initiative. It will therefore be evaluated ex-post if based on the different interests that the parties have in the project, the PPP was the best alternative

The first chapter deals in general with the theme of public-private partnership in the world and in Italy, providing descriptive statistics and notions on its regulatory framework. The attention is then directed towards the Italian context, illustrating its characteristics and its functioning. In the second chapter, the other central theme of this thesis will be treated, namely the renewable energy communities (RECs). The chapter provides a brief introduction to the functioning of the electricity system in developed countries and the various innovations and technologies that aim to transform it in the near future, such as IoT technologies and energy storage systems, essential elements for the implementation of Smart Grids and so of the REC. This study was performed using engineering concepts and a literature review. The second part of the chapter, on the other hand, concerns a study of the literature on RECs, which provided excellent starting points for the purposes of the analysis of chapter 3, in which the case study of Montevarchi was addressed. Here through the Multi-Actor multi-Criteria Analysis (MAMCA) the evaluation of the PPP was carried out in satisfying the various interests of the stakeholders, the municipality and the aggregator, in relation to other ways of creating and managing the REC, including the ESCo model and the traditional procurement model, both methods present in the Italian context in the creation of RECs. The objective of the research is therefore to evaluate whether the Municipal Administration and the aggregator have made the best choice in choosing the PPP to create and manage a REC in the Municipality of Montevarchi, also observing which interests are best satisfied by other scenarios and proposing the MAMCA as a practical methodology that would allow those who want to implement a REC initiative, to choose the alternative that satisfies the multiplicity of interests at the stake of the various stakeholders in a clear and transparent way and involving them from the first stages of the creation process.

Chapter 1
The Public-Private Partnership

1.1 Public-Private Partnerships: a definition

Among the main tasks of the government is to provide public services at a reasonable cost and to create and maintain efficient large-scale durable infrastructure (schools, highways, hospitals, power plants, etc.) that provide a variety of essential public services (Engel , Fischer and Galetovic 2014). The creation of large infrastructures requires huge capital investments and an enormous amount of complexity to manage the financing, monitoring and maintenance of the structure. The costs involved in each phase of the construction of public infrastructures are often inflated because public administrations do not have the skills and knowledge necessary to develop the project from the design phase to the testing phase and subsequent operational management. These shortcomings can give rise to a series of inefficiencies deriving from the construction of public infrastructures that are built and then kept operational by two distinct bodies. This could lead builders not to integrate future operating costs into the design phase, which in this way will burden public spending. Furthermore, it is demonstrated that governments often encounter the so-called "agency problem", preferring to build new projects rather than investing in the maintenance of existing infrastructures or even in their upgrading, to obtain greater political visibility (OECD 2017). Other elements that can make public supply inefficient are the unfair price of the service, set very low for political reasons, and the vulnerability of the government to submit to construction lobbies. In fact, large companies often exploit their economic power to obtain more favourable contracts or renegotiations by using strategic delays in the construction of infrastructures that would have a political cost for the government in office.

Public-Private Partnership (PPP) aims to solve this issue. PPP is generally defined as a long-term contract where the parties are the State, called the Licensor, and a private company, the Concessionaire, that provides the infrastructure. The cardinal feature of the contract is that the financing, construction, and maintenance activities are in charge of one single entity (Engel, Fischer and Galetovic 2014). During the contract, the concessionaire manages the asset and is responsible for the correct use of the same, being entitled to grossing user fees or through the public entities' canons (Paredisi 2017) depending on if the infrastructure is a hot or a cold work (De Luca 2016; Martiniello, Saracchi 2007).

Iossa E. and Martimort D. (2014) have listed the following three main features of PPPs:

- Bundling
  A key feature of the PPP contract is the integration of the design, construction, financing, and project management phases that may be in the hands of a company, a consortium that includes a construction company and a plant management company.
- Risk transfer
  In an infrastructure project, risks can arise from the design, construction, and facility management phases. These, in a PPP contract, are entirely contractually transferred to the private party. The public entity set ex-ante the basic standards and the service specifications and leaves all the responsibility to the licensor for the achievement of the defined milestones for each phase of the investment.
- Long-term contract
  A PPP contract typically lasts from 20 to 35 years, during which the concessionaire will receive payments directly from the public body or from the user fees. The project's length is an additional risk source for the concessionaire because of the exogenous variables that can affect the revenues or cost stream that could make the previewed Internal Rate of Return (IRR) of capital doesn't comply with respect to the one defined ex-ante. On the contrary, the extension of the expiration date of the contract can play the role of a risk-hedging instrument in the event of a rebalancing procedure. Indeed, whether a cash flow shortfall happens due to an unforeseen increase in operating cost, it could be recovered through an extension of the contract, maintaining the revenue side unchanged.

PPP contracts can take on different configurations depending on the degree of delegation conferred on the private subject, the contractual organizational structure and the destination of ownership of the asset at the end of the contract. Each of the following alternatives gives the individual a different degree of responsibility.
Among the concession contracts, generally, three types of contractual configuration can be found: the BOT (Build-Operate-Transfer), the BOOT (Build-Own-Operate-Transfer) and the BOO (Build-Own-Operate). The BOT is a private sector participation model in which the public body establishes a tender procedure in which it supervises all phases of construction and operation, plans future maintenance and carries out these activities in compliance with the predetermined technical requirements established by the body public to which, at the

contractual term, the ownership of the asset is conferred. The BOOT differs from the BOO in that the private party is also the promoter of the project and the source of revenue for the private sector generally derives from user tariffs. Finally, BOO contractually involves several distinct subjects (investors, builders, operators, etc.) with the public body, making the latter's activity very complex in coordinating the various skills necessary for the implementation of the work.
The solution that most involves the private sector is the DBFO (Design, Build, Finance and Operate) scheme in which it acts through a vehicle company (SPV) that enters into contracts with the private sector, the credit institution and the public body.
With this last solution, the ownership of the new infrastructure is in the hands of the public, which oversees all the phases previously referred to through the SPV. The suppliers of goods, services and financing participate in the capital of the SPV to finance the project and once the business is operative, the government provides the contractual payment flow called the availability payment and an annual operating and maintenance fee (O&M). Other fees may be paid based on what is contractually defined (European Commission 2003; Akbiyikli, Eaton 2005).

1.2 Key issues of PPP

In structuring Public Private Partnerships, the public and private actors face several obstacles in dealing with the project's complexity, that if not properly treated, could lead to the failure of the whole initiative causing unpleasant losses for both parties involved and the final users. Triantis (2018) developed an analysis based on the post-mortem experiences and project finance participant discussions that led to project failures. The sample includes initiatives from all around the world taken between 1987 and 2014 coming from different sectors. Through this work, the Author reported the main key issues that must be carefully managed by the private, to structure successful projects and not neglect some fundamental aspects that are indeed crucial for the success of the initiative.

Strategy and project objectives

One of the first reasons of PPP failure is the apparent mismatch between project execution and corporate strategy and project goals. Thus, without a well-thought-out project strategy, project objectives are vague, confusing, and unsubstantiated. In this situation, project goals are influenced by over-optimism, and the problem is exacerbated by wishful thinking that creates unrealistic expectations. This applies to the purposes of some project sponsors or developers and other project stakeholders, including public bodies. In the absence of a clear project strategy that matches the overall strategy of the project stakeholders, conflicting interests and goals of the participants can lead to cooperation problems, leading to lengthy contract negotiations and project delays. Such environments are characterized by difficulties in communicating, coordinating, cooperating, and collaborating, leading to mistrust and indecision. Another factor that contributes to project failure is that project goals do not match project requirements. In other words, there is a gap between project specifications and performance requirements and unrealistic sponsor expectations and goals, resulting in inaccurate cost estimates and different perceptions of project fundability. Another source of error related to project sponsor strategy and project objectives has to do with project portfolio management. Specifically, there is little consideration and analysis of project impacts on portfolio allocation and risk composition in current project funding practices. This leads to unbalanced portfolios in terms of risk exposure, vague strategic intent and clear objectives, and suboptimal asset allocation, to not neglect the number of human resources that would be employed in the project development.

Screening and Preparation

Projects that don't have a clear strategic direction will cause deficiencies in the crucial phase of preparation and project screening. Sometimes sponsors limit their attention to the technical and financial viability, ignoring if they can develop the project that require particular human resources specializations, a dedicated team, an external consultant support or could be developed with alternative investments solutions. Even if it is possible to develop some standardized project screening and evaluation templates, however, is always true that each project is different, and requires tailored solutions. In some cases, the SWOT analysis is a basic tool in assessing the degree of deficiencies of the sponsor company in developing a specific project. The solution to these issues is that Project Formulation Officer must guarantee clear and complete processes, integrating budgeting and planning, and formulating if it is necessary, an ad-hoc financial model, making correct use of data and assumption inputs.

Bidding and Procurement

Opaque and unclear selection criteria from the public entity could lead to several communication misunderstandings and activation of clarification-seeking procedures that lead to the wrong estimation of development costs, longer negotiations, delays, and cost overruns. Often public entities hire external consultants to assess if a proposal is fair and coherent with the objective declared by the sponsors. This implies an additional implicit cost for the private due to the loss of property information that could undermine the future implementation of innovative and profitable deals.

Skill and Competencies

The resources required to structure a PPP project require a broad set of experience and skills: engineering, financial modelling, tax and legal. However, in a corporate environment, these are compartmentalized and so not properly integrated to ensure the correct exchange of assessment and opinions about the different points of view of the project. For these reasons is fundamental the role of a competent project manager in having the necessary project finance knowhow, the capacity to select the most appropriate external consultant and to discern the advice coherently with the objective and the vision of the sponsor company, furthermore, to delegate each task of the project to the best suited human resource for that role.

Project Economics

The undervaluation of the costs and the overestimation of the revenues is one of the principal causes of the failure of the PPP project. These valuation distortions are often coming from erroneous assumptions that contaminate the forecasting activity and so the financial model's predictions. These biases are coming from a lack of reality checks of the model assumptions, poor due diligence and feasibility study, incomplete risk assessment and inefficient risk management approach. Hence it is clear that these steps must be made precisely, and it is fundamental to test the assumptions used with a reality-based approach, furthermore, it is likewise important to develop an effective sensitivity analysis that could capture the value fluctuation of the project under different scenarios. These checks must be integrated into financial models to accelerate the overall process and so reducing the costs of this investment step.

Technical Issues

Technical issues become relevant in presence of projects characterized by a high degree of technological and project complexity build in with a rigid organizational structure that leads to cost overrun in case of subsequent modifications and interventions. For these reasons, sponsors that must face the use of new technology has to also consider the costs of possible future interventions, especially during the operating phase, and structure a project that could embrace the future technology without excessive or hidden operative costs.

Risk management and contracting

A project risk is an event, development, or change, whose occurrence adversely affects the project's ability to achieve its expected goals. Risk management involves identifying these factors, evaluating their impact, controlling their likelihood of occurrence, analyzing and prioritizing, mitigating, and monitoring them to manage their impact. For these reasons is one of the key issue in structuring a PPP initiative. Inefficient risk allocation doesn't come only from sponsors' negligence or incompetence but also from an inequitable risk allocation. The latter creates relational problems among the different stakeholders, causing resentment, mistrust between the contractual parts and delays. For these reasons it is also necessary to sign precise and fair contractual agreements, that aim to avoid unbalances between parties' benefits and responsibilities and don't leave any room for misinterpretations. The harmony between the agreements signed between the different stakeholders is the key to ensuring a correct risk allocation and well-defined competencies among project participants.

1.3 Data and Trends

1.3.1 PPP in Low and Middle-Income Countries

Across the World, Private Participation in Infrastructure (PPI) is increasingly important both in absolute terms and in the percentage of total public investment, especially in the developing world (Fabre, Straub 2021). In this paragraph, it is reported a descriptive analysis made through a personal elaboration of data taken from the World Bank database concerning Private Participation in Infrastructure (PPI) in Middle- and Low-Income Countries. Data are selected taking into consideration all the greenfield and brownfield active projects for all the areas and sectors available in the database, as that Sub-Saharan Africa (SSA), East Asia and Pacific (EAP), European and Central Asia (ECA), Latin America and the Caribbean (LAC) and South Asia Region (SAR).

Figure 1.1 illustrates the trend in the number and volume of active Brownfield and Greenfield investments in the Developing World. In 2021 the PPI involves almost 60 billion dollars for a total of 210 projects. In the chosen time window, the investments in greenfield projects constantly overcome the Brownfield, which in 2021 counts 16.8 billion dollars.

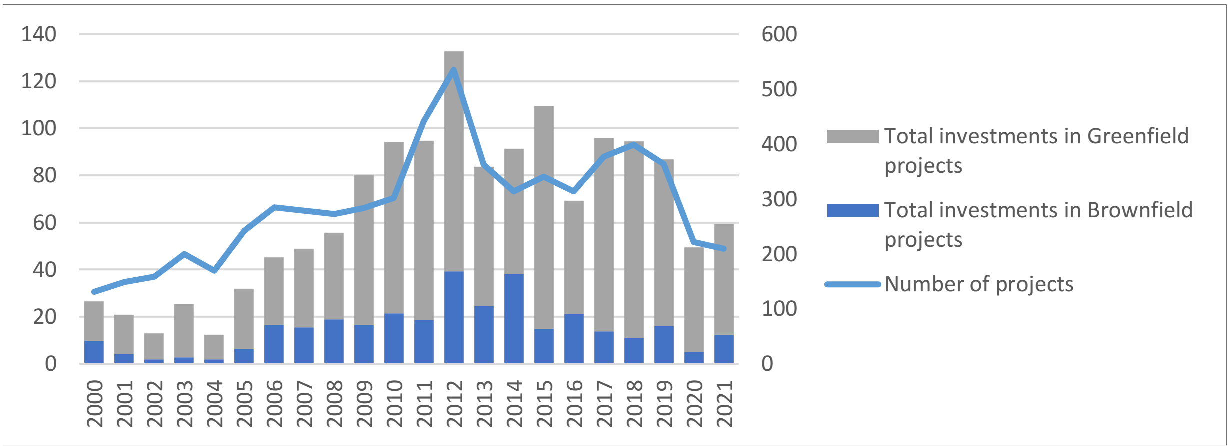


Figure 1.1- Trend in the number and volume of active Brownfield and Greenfield investments in the Developing World Personal elaboration of World Bank Data

Figure 1.2 reports the role of each geographic area and the relatively low and middle-income countries on the investment in PPI in 2021. East Asia and Pacific (EAP) region group 40% of the investments made, thanks to the central role of China, which cover 68% of the entire Region for a total of 10.4 billion dollars, followed by Vietnam, the Philippines and Cambodia. China has increased the number of PPI investments thanks also to the expansionary monetary policy, that provided liquidity to the national bank systems, facilitating lending operations and economic recovery after the 2020 pandemic. Europe and Central Asia (ECA) recorded an increase in PPI investments from 2020 of about 2.3 billion dollars, driven especially by the Russian Federation but mostly by the increasing role of Turkey and Uzbekistan, very present respectively in the airport and energy generation field. The outlook for future investment trends in the region could be seen downwards, due to the war between Russian Federation and Ukraine and the consequences that will have on the whole Region.

In the Latin American and Caribbean Region (LAC), Brazil groups 57% of the total investment in the area and overall, PPI involves almost 0,46% of the total GDP (The World Bank 2021). Many of the investments in this Region involved the field of transportation and water treatment. From the numerous tender processes that are in the elaboration phase, especially in the field of the renewable power sector, port, and airport, it is possible to expect that in the next years the PPI market will continue the growing trend that started some years ago.

In Sub-Saharan Africa (SSA) during 2021 there was recorded a decrease in PPI investments, however, thanks to international contributions several strategic national infrastructures were set up, especially in the Democratic Republic of Congo and Mozambique, that implemented two large projects of port and power generation field, each of roughly of 1 billion dollars.

India, making part of the South Asia region, continues its infrastructure expansion plan, especially in the airport field. In the next few years, it is expected to increase its PPI thanks to the quinquennial plan "National Infrastructure Pipeline" aiming for the improvement of national strategic infrastructures.

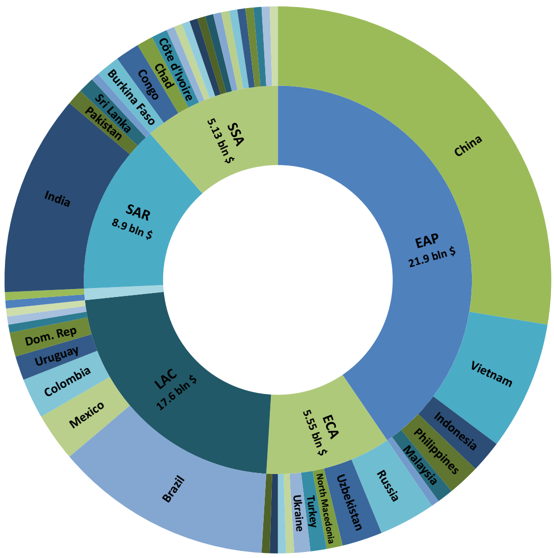


Figure 1.2 – Amount of investments in PPI project following geographic driver
Personal elaboration of the World Bank Data

Figure 3 report the sectorial shares of infrastructural investments with private participation in each year from 2005 to 2021. It is evident that the transportation sector is over the years the one that involves the majority of the PPI of the total, and it is the only one that recovered after the pandemic slump in value, bouncing from 31% in 2020 to 47% of the total of the investments at the end of 2021, despite the difficulties of the SAR, especially for India, in facing the Delta Covid variant, causing inevitable slowdowns from lockdown and other containment measures. The energy sector in 2021 involved 37% of the total investments in PPI, which decreased by 23% from the 2020 levels when it was 60% of the total. In 2021 only investments in the electric generation field were made in all the Regions, except for LAC and SA which present investments that are 1% of the total, but only in the field of electricity transmission. Considering the installed capacity, 71% of new energy generation projects in 2021 were renewable, despite the average of 61% in the last 5 years.

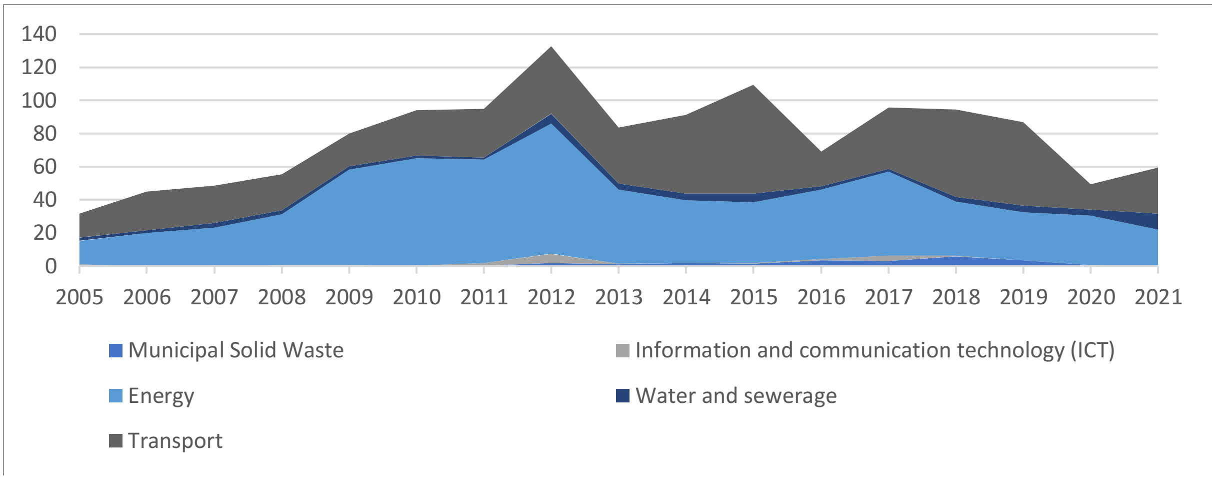


Figure 1.3 - Sectorial shares of PPI from the year 2005 to 2021
Personal elaboration of the World Bank Data

1.3.2 PPP in Europe and Italy

Data on PPP were not available for this region from the World Bank database, however according to the topic of this dissertation, it is useful to provide some insights about the energy and PPP market in Europe and Italy. For this reason, below are reported some statistics taken from the 2021 report of the European Investment Bank (2022).

The European PPP market, in 2021 is shrinking by 13% concerning 2020, for a total of 8 billion euros. This highlight a negative trend that started in 2019 that seems to become structural over the years, exacerbated by the remarkable role of the Covid Pandemic that has slow the procurement and preparation stages in all the observed Regions.

The interesting fact is that, however, the role that plays PPP investments in Italy is central, as it is possible to see in Figure 4. Indeed, among the three largest closed transactions in Europe in terms of amount invested, the first one is the Pedemontana Lombarda Motorway, for a total value of 2.1 billion euros which makes Italy the first market in terms of value. France instead is in first place for a number of deals, which are 17. Furthermore, Italy over the years has increased notably the PPP number of projects, starting from less than 1% of the overall infrastructure investments in 2002, to 17% in 2018 (Egidi, Leonforte, Nobile 2022)
Concerning the sectors involved, Figure 1.4 shows that the Transport count 6 billion euros, increasing by 2 million and 4 projects from 2020, that in 2021 were sixteen. The second sector is the Environmental one, which includes for instance the renewable energy generation plants, and it counts 9 projects for a total of 866 million euros, including four district heating projects located in France.

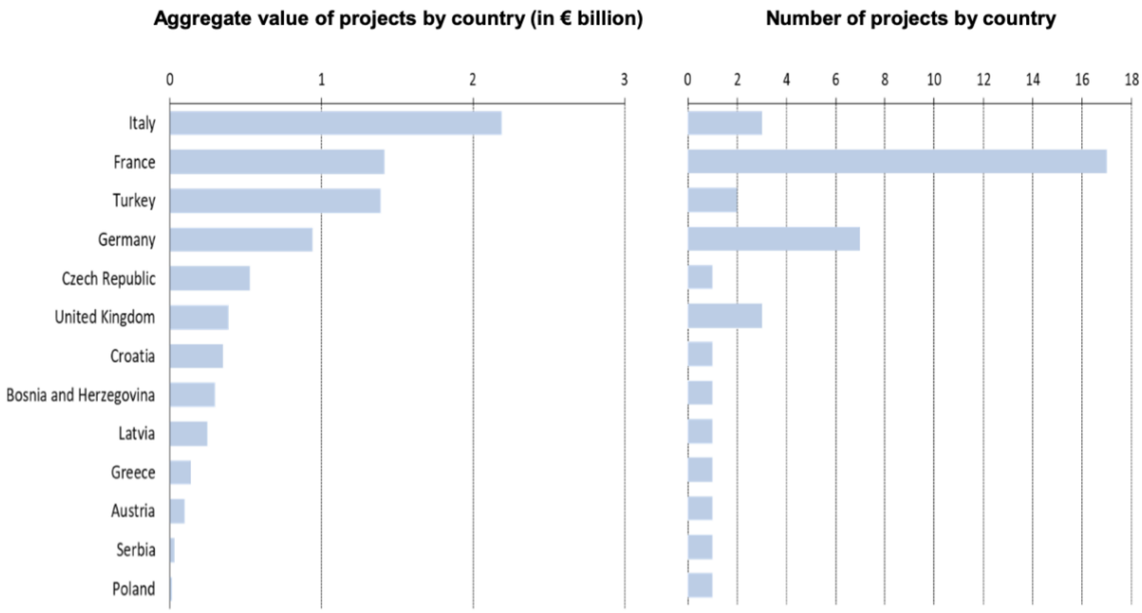


Figure 1.4– Euro numbers of PPP projects in 2021
Taken from EIB 2022

From Egidi, Leonforte and Nobile (2022), the PPP initiatives in Italy are present for about 20 years, although it has been present in its legal system since 1994. This is because the complete legislation was issued with Legislative Decree 163 of 12 April 2006. of the Code of Public Contracts, therefore relatively late compared to other European countries. This one gave impetus to the realization of numerous projects in the field of:

- Transport (e.g., toll roads, undergrounds, light railways, ports, airports, and parking areas);
- Social infrastructures (e.g., schools, hospitals, prisons, sports facilities, parks, public

housing);
- Energy and water (e.g., public lighting, energy efficiency projects, aqueducts, power plants, energy from waste facilities);
- Telecommunications and digital (e.g., broadband);
- Defence (barracks)

In April 2021 the National Recovery and Resilience Plan (PNRR, 2021) were approved by the Italian Parliament. It allows to access the 750 billion Euro of funds of the Next Generation EU. It provides investments in six areas, as that:
- Digitization, innovation, competitiveness, culture and tourism;
- Education and research;
- Energy transition;
- Inclusion and cohesion;
- Infrastructure for sustainable mobility; and
- Health and resilience.

PNRR however does not specifically provide if the funds shall be used in PPP projects, however, can be plausible to retain that these funds can indirectly foster the growth of the PPP market since the fields of application are very similar to the ones applied by PPP schemes. In this way, these funds can be used to increase the financial availability of the Contracting Authorities to carry out all the preliminary steps of the investments like feasibility studies and project design. Merging the financial availability of the various parties involved and the private party's know-how allows the implementation of solutions in the country's strategic sectors and fills the gaps that traditionally dampen this kind of public investment.

1.4 The Italian legislation

To fully understand the role of PPP in Italy, it is appropriate to understand how the PPP is regulated by Italian law, for instance, who are the actors who can participate between and any PPP schemes that are available in terms of contracts and the differences between them. This part is mainly focused on the possible solutions that can be applied to the energy sector, for this reason at the end of the paragraph the Energy Performance Contract is treated, as a contractual tool widely used in energy efficiency PPPs (Carbonara, Pellegrino 2018). The analysis is developed using the five-W question to summarize and briefly overview the Italian legal context and its actors.

1.4.1 What

To Article 3 “definitions” of the Italian Code of Public Contracts, the PPP is a “written contract of pecuniary interest by which one or more contracting authorities confer to one or more economic operators for a pre-established period of time [...] a set of activities that involves realization, transformation, maintenance and operational management of a work in exchange for its availability, or its economic exploitation, or the provision of a service related to the use of the work itself, with risk-taking in accordance with arrangements identified in the contract, by the operator”.

Article 3, compared to the repealed Legislative Decree NO.163/2006, gives a broader definition of PPP, especially concerning the object of the contract, the duration and the distinction between works with a fee recognized by the granting authority (referred to as "cold work") and the works with a fee on the user ("hot work") (Giorgio et al. 2018).

At the European level, the topic was introduced by the "Libro Verde" (2004), which is a quite general but important document since it provided some hints in treating and configuring the discipline of this instrument, defining general characteristics and variant but not giving definitions and practices, left to the competence of national legislators. For this reason, in this section, is treated only to the Italian legal framework, since at the European level the discipline is quite general and so not directly useful for the purpose of this dissertation.

Article 180 of the Code of Public Contracts delineates the fundamental characteristics of PPP contracts, which are:

- The object of the contract, which could also embed the design of the facility and the services correlated
- The private party must be paid through public fees or user fees
- The private party must bear the construction, availability, and demand risk
- It is possible for the private party, to receive a public contribution with the aim to reach the 49% of the total investment

1.4.2 How

The code establishes six procurement procedures that public entities can implement to enforce a PPP contract which actually is the same applied to traditional public contracts (Paredisi 2017; D. Lgs. 50/2016). Compared to other public contracts, however, PPPs have the advantage that public authorities have greater flexibility in determining how best to manage procurement processes, provided that the general principles of economy, efficiency, fairness, equal treatment, and transparency are respected during the whole procurement procedure, that can be:

- Open procedure
- Restricted Procedure
- Competitive procedure with negotiation
- Competitive dialogue
- Project finance reliance
- Innovation partnership

As treated by Egidi, Leonforte e Nobile (2022), in Italy the most used is the open procedure, because it allows guarantees the larger participation of tenderers and it increases the chances for the public administrator to choose the best alternative considering the best offer in term of technical and economical characteristics that are present on the market. The competition call is published along with a project outline and specifications for the works or services involved, a draft PPP contract, and an economic and financial plan that defines risk sharing between the private and public sectors.
The decision to implement a PPP operation must be preceded by a preliminary investigation that would analyze the demand and the offer of the proposal, the techno-economical and socio-economic feasibility, the various risks of the operation and the assessment of the convenience with respect to other forms of contract. Even if it is not specified in Code, Authorities run this activity by publishing a request for Expression of Interest addressed to the private parties in which the Contracting Authority can evaluate the feasibility of the project and the deciding the if the PPP is the best solution to be implemented (judgment No. 696 of 1 April 2019 of the Regional Administrative Court of Milan and judgment No. 843 of 8 February 2011 of the Council of State).

The private party often uses bank loans to finance the operation, which is why Article 165 of the Code of Public Contracts has established some measures that aim to ensure the obtaining of the necessary financing and a sufficient level of bankability of the project. These measures include the obligation on the part of the public body to prepare the tender documents in order to guarantee the correct level of bankability, and the possibility for the Concessionaire to carry out a preliminary consultation with the economic operator before the tender procedure to ensure that the loan disbursing and finally the possibility of including in the call for proposals the obligation that the offer is accompanied by a declaration of interest from one or more Financial

Institutions that finance the operation. Another important element in this stage of the investment is the monitoring of the risk allocation, which must be in charge at the private party. The ANAC (Autorità Nazionale Anti Corruzione) defined adequate monitoring procedures for Public Bodies that aim to ensure that all the risk should be in charge of the economic operator. An efficient risk allocation, especially of the operating one, is essential for the correct accounting of the PPP operations off the Public Balance Sheets (Cartei 2020). Hence the contract must define correctly how the risks are allocated, which are monitoring systems implemented and the consequences that would happen in case of unexpected contract resolution (Giorgio et. al 2018).

According to the Italian and the European legal system, there are two forms of PPP, the contractual and the institutionalized (Paredisi 2017). The more used in Italy are the contractual ones, which allow for obtaining the same results, limiting however the public responsibilities in the due diligence phase (COM 2004).

In Contractual PPPs the private party oversees the project under the control of the public entity with a difference according to the chosen contract type, that according to the article 180.8 of the Code of Public Contract can be:

- Public works concessions
- Service Concessions
- Project Finance contracts
- Service concession agreements
- Sponsorship
- Financial leases of public work
- Availability contract
- Energy Performance Contract (EPC)

On the contrary, in institutionalized PPPs, the public and private entities hold participation in an ad-hoc company created to build, maintain, and operate a project or provide a service of public interest. In this kind of configuration, a public entity can maintain more control of the asset since here the corporate law is applied and so each contractual part exercises its power in relation to its held participation quotes (Paradisi 2017). In this kind of initiative, the public-private participated society can be (Gallia 2008):

- Mixed companies with prevalently public capital;
- Mixed companies with prevalently private capital;

- Mixed companies established pursuant to the code civil;
- Urban transformation company.

1.4.3 Who

Italy is composed of 19 Regions and two Autonomous Provinces. According to this, Italian authorities can be grouped into three types: the central governments, regional governments, and local governments, with different but concurrent and coordinated power and functions. All these bodies are entitled to set up a PPP and be the Contracting Authority. The role of promotion and technical and administrative coordination activities to planning and approve the infrastructure implementation is the Ministry of Infrastructure and Transport, in concert with regions and Autonomous Provinces. The Code give to ANAC the role of surveillance of the construction of the infrastructure, giving the role to approve studies, guidelines, and soft regulation tools like, for instance, standardized contracts, to easier and facilitate the PPP implementation process. The Supreme Council of Public Work is in charge to issue a mandatory opinion for designed projects of national relevance or financed by the state at least by 50% and with a value above 50 billion euros (Egidi, Leonforte e Nobile 2022).

The Contracting Authorities are disciplined again by article 3 "Definitions" of the Code of Public Contracts, at the letters "a", "f" and "g". Among them are listed the State administrations, the local and regional Public Authorities; other non-economic public bodies; bodies governed by public law; associations, unions, consortia, in whatever form, made up of such entities. There are present also the "other contracting entities" which are subject to the norms of the same Code.

The letter "p" instead defines the figure of the economic operator. It could be a natural or legal person, a public body, a grouping of such persons or bodies, including any temporary association of undertakings, or an entity without legal personality, that provides the realization of works, the furniture of products or service provision.

The typical sectors to which can be applied the PPP for the management and construction of facilities and/or services in Italy are transportation (motorways, bridges, ports, local public transport), energy (production plants from renewable sources, energy efficiency, street lighting), environment (MSW disposal, waste to energy plants, water treatment plants), sports facilities (sports facilities, swimming pools, multipurpose sports centres), structures with cultural value (conference centres, property recovery / historical contexts, museums) and other public works such as schools, hospitals, buildings used by the Public Administration, car parks and barracks.

1.4.4 Why

In the last twenty years, Italy has generally been experiencing an increasing Debt / GDP ratio accompanied by a slowdown in the general indicators of economic growth, especially during the last financial crisis of 2008 and subsequently of the sovereign debt of 2012 (Istat 2022).
Furthermore, it is specified in the dossier of the Impact Assessment Office (Giorgio et al. 2018) of the Senate of the Republic, that despite the Italian public expenditure on GDP is around 50%, the investment component is only 2% and between 2008 and 2016, both public and private investments fell by about 27%, especially in the South. To aggravate this picture, there is the fact that almost 90% of the total are private investments, reserving only a small percentage to those of a public nature which an advanced state such as Italy is, needs to maintain an adequate level of public services.
For this reason, the need for Italian infrastructural investments is slowed down by a context characterized by scarce financial resources and spending limits that block the room for manoeuvre even of the Local Public Bodies (LPE), which, thanks to the latest reforms, are acquiring an increasing financial autonomy by taking responsibility for planning and sourcing resources independently of the Central Government. Due to these changes, LPEs find it difficult to raise capital from the credit market, which in the last decade has drastically decreased the number of loans granted to these institutions, as they are often not financially bankable and no longer provided with the guarantee of the State. For these reasons, PPPs can address these problems by introducing new funding instruments.
From the 2015 Stability Law, the DIPE (Department for the planning and coordination of economic policy), has indicated the use of PPPs as a tool to enhance the public investments that Italy needs by providing guidelines, documentary sources and collaborations both to the private sector and public bodies.
Despite all these considerations that report the importance of private participation in infrastructures in an Italian context characterized by enormous budgetary constraints, the PPP is not exploited to its full potential for several reasons, for instance, an uncertain allocation of risks in concession, political instability, inadequate tender documents (PPP procedures and contracts) and lack of funds. The government is trying to fill the gap both from a legal and administrative point of view and from an economic point of view, thanks to the PNRR and the

possible indirect impact it could have on the PPP market (Egidi, Leonforte and Nobile 2022). At the European level, the European Investment Bank is playing a key role in promoting PPPs through its political activity and the creation of the European Center of Competence on PPPs, charged with advising EU Member States in supporting PPP initiatives and practices (Liebe and Howarth, 2020). However, from Ivanova (2018), the responsibility for the inadequacy of the regulatory framework is, in some cases, the responsibility of the national government, as demonstrated by France, Spain and Greece which shows that even in a European context that seeks to actively promote this instrument, it is necessary that the legislator has a political will to work to solve the need for a more streamlined and functional bureaucracy.

In addition, as also reported by Cedrick and Long (2017) and Steffen (2018), these factors risk indirectly to slow the energy transition towards renewable resources, as PPP is seen as a key element that can accelerate this type of change.

1.4.5 The Energy Performance Contract

For this dissertation, it is useful also to focus the attention on the Energy Performance Contract because of the intensive use of this instrument by the Public Administration and Energy Service Companies (ESCo) in PPP energy efficiency projects. The fact that both public entities (municipalities, Regions, etc) and the ESCo are both aware and practical of this contract (Mazzantini S. 2022), allows seeing at his contract as one of the possible solutions to the issue of the application of PPPs on Renewable Energy Communities (REC).

Legislative Decree 102/2014 defines the EPC as an agreement between the beneficiary and the supplier of energy savings, monitored during the life of the contract, in which the counterparty is paid based on the degree of energy efficiency achieved or other predetermined criteria, economic savings included.

From Benanti (2017), there are generally two main types of EPC contracts: Shared Savings and Guaranteed Savings. The first provides that the savings are distributed between the two parties during the life of the contract according to a predetermined percentage based on the amount of the investment made by the ESCo, the duration of the contract and the payback time. Usually, the contract has a duration of about 5/10 years. Contractually it can also be defined that all savings could be withheld entirely by the ESCo to reduce the duration of the contract.

The second option instead provides that, if the predetermined savings defined in the feasibility study are not guaranteed, the ESCo must pay an indemnity covering the difference between the expected and actual performance. Therefore, from the type of EPC, it is clear the role of the contract in helping to concentrate the efforts of the ESCos to achieve the predefined savings as the savings achieved play a central role in the ESCo's revenue function.

In 2014, Italy has transposed the 2014 EU directive, and through the ENEA (Ente per le Nuove Tecnologie, l'Energia e l'Ambiente) has defined the minimum elements that an EPC contract has to contain and a contract and a technical specification scheme's. The essential elements that were considered in making the EPC contract compliant with the directive (Fasano et al. 2015) are:

1) The energy requalification interventions and the amount of expected savings that are to be guaranteed by the ESCo
2) Assessment and monitoring activity during the lifetime of the contract
3) Verification of the facility performances

The commitment of the ESCo to ensure to the P.A. a minimum energy saving is considered a performance obligation, and a violation of it is comparable to a contractual breach. If the results after a determined period (typically one year) are not satisfying, the ESCo must make investments to bring back the performances to a guaranteed level.
For this characteristic, the EPC contract is seen by several policymakers as a useful tool to reach as quickly as possible the reduction in CO_2 emissions on large scale. Due to these characteristics, the EU considers this contract a fundamental tool to reduce the energy consumption of the Member States. This part also focusing also on the technological innovations that found application in this field, which shapes

Chapter 2
Smart Grid and Energy Communities

This chapter treats the other core topic of this dissertation, as that the RECs. To do so, firstly the initial paragraphs will provide an overview of the basics of the current Electrical Power System (EPS) with their elements and how they function to produce, distribute, and store electricity. To do so, it has been provided basic engineering concepts and a brief literature review, focusing on the technologies used and studied in the developed world and the ones applied to RESs, to comprehend the evolution of EPS and his future perspectives. Afterwards are presented the RECs, which represent the "bridge" between the present and the future of the EPS, explaining how they could make a difference in terms of energy justice, environmental protection, and energy efficiency, themes that are more and more important nowadays also from the regulative perspective. The RECs are then analyzed from the legal perspective, reviewing the normative path that has brought them from a European to the Italian legal framework. This part is completed by a brief comparative analysis of how this phenomenon has found space in the different EU countries also before the introduction of the RED II Directive. It has been curious to discover that, for instance, countries like Germany and Denmark have not RECs compliant with the RED II directive, furthermore they haven't even transposed the directive in their legal system, however, this is not because of political negligence, but rather thanks to the existing presence of RECs in their territories well before they became of communitary interest. Then focus was brought then on the Italian context, analyzing how Italy and her regions have transposed the directive, the incentives previewed and the state of the art of a regulative process that is still evolving.

The end of the chapter is the literature review part concerning the REC topic, organized by thematic areas and mainly focused on cases present in developed countries. This process was extremely important to assess how the REC topic has been faced from a scientific perspective and from which academic sphere the issue was treated. The research was conducted by setting as search words quite general terms relating the RECs like "Smart Grid", "Energy Communities" or "Micro-Grid", to provide an analysis as broad as possible. It has been discovered that most of the articles concerning this topic are part of the engineering research field, such as technical-economical optimization method implementation, impact assessment on REC outcomes or analysis of the motivations behind local population participation and acceptance of Renewable Energy Sources (RESs). However, some articles in the field of management were discovered analyzed and then selected to interpret and make scientifically relevant the analysis of the case study of Montevarchi that will be treated in chapter 3.

2.1 Basics of Traditional Electric Power System

To assess the impacts that the RESs and the RECs have in transforming the electricity market and the network, it is fundamental to provide basic concepts about the current electric power system and the drivers that are pushing it toward a new energy infrastructure system.

Refaat et al., (2021) help with this aim, reporting the principal characteristics of the current traditional Electric Power System in developed countries where the infractructureis are already existing, which are the Centralized electric generation and the unidirectional power delivery system.

Energy flow follows a top-to-the-bottom scheme, in which the energy generation process is carried out by a bulk power facility which feeds the energy produced into the grid. Close to the generation site, it is transmitted with high voltage, then as it is distributed towards residential and commercial users, it will be converted firstly in medium and then in low voltage power flow, suitable for small-scale consumers. These steps are represented in Figure 2.1.

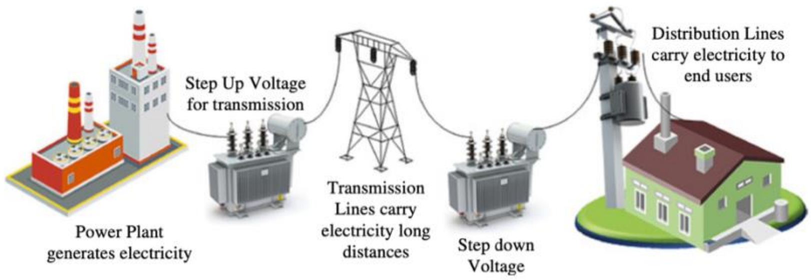


Figure 2.1 – Energy flow scheme - Taken from Refaat et al., (2021)

Among the different transmission systems, there are the overhead lines or underground and underwater cables, these last more costly by 4 to 10 times compared to the overhead ones. The high voltage lines can be classified among the High Voltage Direct Current (HVDC) and the High Voltage Alternate current (HVAC), this last is more used because more efficient. The high voltage that today is normally used is 100 kV (Jamal T., Salehin S. 2021), which of course is very high compared to the need of a medium household need, which is around 3kW. The power of the Power Plant and its distance from the final user, deeply influence the design of the infrastructure because of the electricity dispersion that occurs in the distribution system thank to electricity characteristics. From Figure 2.2 it is possible to see an example of this energy-related feature that demonstrates how more distant are the power sources to the final consumer, the more costly becomes in terms of electricity generation and facility capacity.

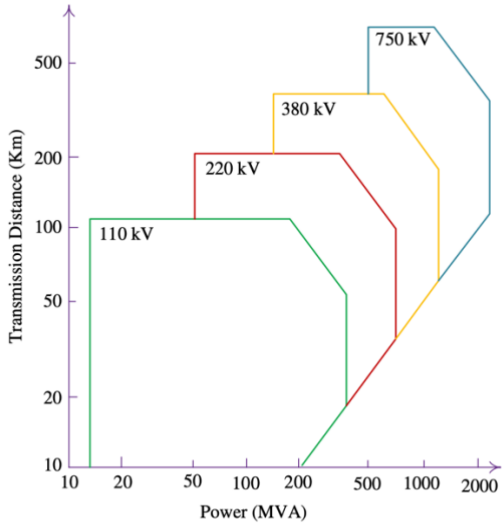


Figure 2.2 – Energy losses - Taken from Refaat et al., (2021)

The power distribution systems in most countries are deteriorating because of the natural expected lifetime of activity since they were built around the 50s. The cost to upgrade and restructure them is estimated to be very high and unaffordable for many developing countries but also for many advanced countries. For these reasons, the authors retain that the existing infrastructure could be used to transact toward the so-called "Smart Grid", which allows for reducing the costs of modernizing the actual electric network by applying new technological solutions on the market at an affordable price and the integration of the DERs.

2.2 Toward the Smart Grid

Thanks to an exceptional demographic expansion and rapid urbanization, especially among developing countries which are experiencing the transition from an agricultural to an industrial economy, forecasts foresee an increase in energy needs by from 2012 to 2040 by 48% (Erenoğlu et al. 2019) and, consequently, the estimates on greenhouse gas emissions are destined to be seen on the upside, since most of the energy sources used in the world are fossil origins, such as natural gas and coal, especially for countries such as China, India and the United States (Ember 2022).

This has grown the concern related to global warming that will provoke increasing ocean levels, polar ice melting and issues with biodiversity. For these reasons, several Western Countries and recently also several developing Countries, are promoting the implementation of RESs plants,

through well-defined long-run objectives, like the SDGs, the European Red II and the recent US Inflation Reduction Act of 2022.
RESs are in many cases Distributed Energy Resources (DERs), which goes in contrast with the paradigm that has followed the current one-directional and large-scale traditional Electric Power System.
Indeed, from the beginning of the use of solar and wind electric generation systems, they were configured as complementary sources of energy, integrated into the traditional system to function hybridly with the other fossil sources. However, the increase in technological smart applications to the grid, the increasing demand of industrial and residential consumers, and their economic affordability (thanks also to State incentives) made them an optimal solution to exploit all the network and environmental benefits such as the increasing reliability of the grid and lower emission that are able to offers if properly managed (Erenoğlu et al., 2019).

Therefore, relate to the previous motivations, there is a need to transact from a centralized power network to an electric power system in which there are small-scale power generation plants from renewable sources that serve a limited number of users located in their proximity. These systems are defined as Micro Grids (MGs) and are often provided by energy storage systems (ESSs) to manage more efficiently the load fluctuations due to the partial unpredictability of the renewable resources and the users' habits. A small-scale MG structure is reported below in Figure 2.3.

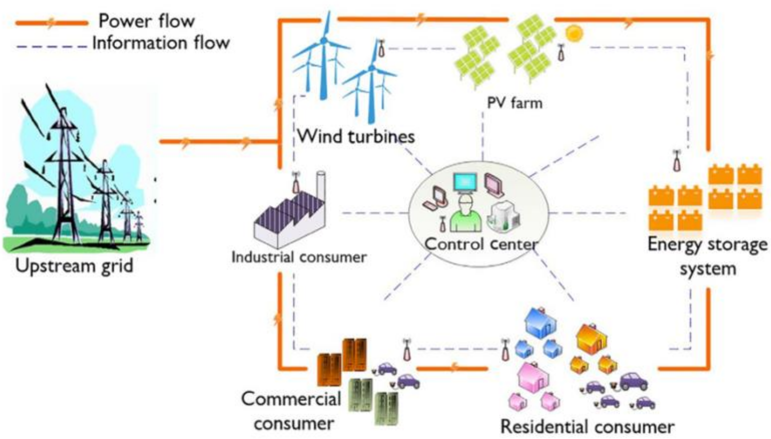


Figure 2.3 – Micro Grid scheme - Taken from Refaat et al., (2021)

MGs are included in the broader concept of Smart grids (SGs). SGs are defined by the Department of Energy (Department of Energy 2003) as an electric power system that integrates the generation and distribution infrastructures with IoT technologies to enhance grid operations

to deliver energetic services and reach environmental benefits. IoT technologies provide real-time information about the consumers' behaviours, integrating them intelligently with the other actors of the grid, such as prosumers and consumers. Hence in some sense, the IoT technologies that are part of the definition of SM, enable the MGs to operate efficiently.
SG architecture is composed of three components: power, communications, and information. Indeed, the implementation of SG is possible only using new technologies that are applied in eight different elements: distributed generation, electric storage system, smart meters, advanced control, integrated communications, sensing and measurement, improved interfaces, and decision support using customer engagement and demand response (DR) (Refaat et al., 2021). These elements are described below.

Distributed Generation

DERs are small-scale decentralized power generation systems that are often located in the proximity of the load. They are modular and flexible energy clean sources, such as hydro, biomass, biogas, solar, wind and geothermal. These sources can be used to implement bidirectional flow power that makes the grid more reliable, reducing the probability of energy outages and network electricity losses over transmission and distribution lines. On the other hand, the prevalence of DG will increase the complexity of the grid, increase voltage and frequency deviations, and create significant stability and control challenges that can lead to management problems. To meet these challenges, coordinated control and management systems must be used to meet customer demands, ensure power system vulnerabilities, and ensure continuity of service (id.).

Energy Storage

Energy Storage Systems (ESSs) are the technologies that allow the use of RESs while ensuring continuous energy supply and grid support (id.). As aforementioned, the ESS allows smoothing generation and consumption peaks or RESs, ensuring energy reserves and improving the grid's resilience. From De Santoli L. (2016) the ES systems can be installed on or off the grid, on the distribution network or in the proximity of the final user and for facilities of different MW. ESSs can be of several natures, such as:

- Electrochemical: batteries that through chemical reactions can store and release electric energy. Among these ESS there are the lithium-ion batteries, often used in smartphones and laptops, nickel/cadmium batteries, nickel/metal hydrides, sodium/nickel chloride and redox batteries with vanadium electrolyte circulation.
- Mechanical: among which flywheels, that store Cinetic energy thanks to the rotation inertia

- Electric: are magneto-electric supercapacitors and superconductors that accumulate the energy in two or more double-layer capacitors
- Chemical: like Hydrogen and syngas that can be used to store energy in underground facilities

The different features of the ESS are summarized in Table 2.4.

Type of ESS	**Denomination**	**Energetic Density [Wh/kg]**	**Charging/ Discharging Efficiency [%]**	**Expected lifetime (Cycles)**	**Memory effect**
Electrochemical	Lithium-ion battery	40/180	80/95	1500/5000	Absent
	Sodium/Nickel chloride	160	90	2500/3000	Absent
	Redox batteries	25	85	Indefinite	Absent
	Nichel/Cadmio batteries with vanadium electrolyte circulation	50/60	60/70	1000/1200	Present
	Nichel/Metal hydrides	40/100	66/92	500/1000	Present
Mechanical	Flywheels	500/5000 W/kW (specific power)	90	1 mln	Absent
Electrical	Supercapacitors	1/10 Wh/kg	95	0,5/1 mln	Absent

Table 2.1 – Energy Storage Systems - Personal visualization of data taken from De Santoli L. (2016)

The choice of a particular storage technology depends on the smart grid context in which it finds application, and the key drivers that guide the choice are economic constraints and technical requirements. The more equipped ESS of energetic density are the lithium-ion batteries and the sodium/nickel chloride batteries, also called Zero Emission Battery Research Activity (Z.E.B.R.A). However, the latter has an internal activity temperature of roughly 300 C, hence very influenceable by external temperatures. Other electrochemical batteries however have the so-called memory effect (Sasaki S., Ukyo Y., Novák P., 2013), defined as the progressive loss of using capacity that occurs if it is repeatedly charged only if it is partially discharged that cause a sensible reduction in expected lifecycles. In term of energy efficiency and durability the flywheels result to be the most efficient, however from the economic perspective, this technology has high development cost and present very design complexity (De Santoli S. 2016). There are also chemical storage systems, that use hydrogen which has the capacity to store energy compressed and stocked in appropriate containers, however, this technology is still being refined and requires a high amount of energy to be produced. Another chemical tool to store energy is ammonia, but also this presents some practical implementation barriers, especially in a small-scale context (less than 1MW power) (Valera-Medina et al., 2018). In addition to these alternatives, there are also thermal ESSs, however, they are applied in other contexts that differ from one of these dissertations.

The study of Subarto et al. (2020) and Kang Miao Tan et al. (2021), analyzing the performances in terms of voltage stability, power balance and the optimization of the ESS of an MG, affirm that is optimal to implement a dual energy storage system in which are combined batteries and supercapacitors. However, in the literature, it was discovered that the factors that guide the choice of a particular storage technology are multiple, and depend mainly on the energy mix used, the types of users and the network size. Sometimes an ESS is not even necessary because there are two countercyclical sources of energy, for instance, the solar that produces during the day and the wind that cover the night consumes, or the habits of the users fit perfectly with the energy supply produced by the DERs. Anyway until 2017, the most used ESS in terms of MW is the Lithium-ion batteries with 35% of the total energy capacity and a total of 1120 MW, while in the second place there are the flywheels with a total of 930 MW (Argyrou et al., 2018). The flexibility and the benefits in terms of savings peak optimization in local electricity markets have been amply demonstrated (Lüth et al., 2018).

Demand Response

DR aims to solve the issue of demand-side control in the MG. Using the Smart Meters and the communication network it is possible for the participant in the energy market to actively make a difference, remodeling their consumer habits to smooth the possible load peaks and so reconcile the demand with the supply of electricity. DR can be implemented in two ways, by load response or price response programs. The first one provides that the facility that manages the SM provides a signal to the users to indicate the short-term peak load through different communication channels, for instance with Smartphone applications. The second one instead aims to decrease the demand by varying prices according to different Price Response Programs, which can be: Time of Use and Dynamic Pricing. The first one is the division in time slots by the utility company by which are applied different pre-determined fixed tariffs to smooth the load peaks that occur daily at certain hours of the day. Dynamic Price instead is a real-time pricing program of the current loads, in which users are hourly notified through internet tools, such as smartphone apps, with the most updated price associated with the load peak. In this way, users are incentivized to postpone their consumption when the tariff is more favourable, as when the supply overpass the grid demand. This solution increases the efficiency by roughly 20 to 60% compared to the preview solution.

2.2.2 Recent advancements in the energy distribution and generation field

For the purposes of this dissertation, it is useful to analyze what has been done in the energy distribution and production field, to comprehend the evolution of the research and the relative drivers that have pushed it toward a Smart Grid system and ECs. The three main drivers of that generally have changed the power infrastructure construction are Decarbonization, Digitalization and Decentralization (Di Silvestre et al., 2018). This is because national policies encouraged decarbonization according to the overall population sentiment that started around the 60' following the "oil shocks" that acted as a catalyst for social-driven initiatives around RESs (Hewitt et al., 2019), the increase in power need require decentralized power generation systems that require new distribution needs, and finally, urban development and digitalization favoured the emergence of peer-to-peer business models that require massive use of technology to ensure transparency, affordability and sustainability (id., Després et al., 2015).
Around these three main drivers, the research in the last decades focused on two main areas: Energy Transition and Energy efficiency with obviously both referring to the functioning of the DESs.

Energy transition

The growth in RESs and so of the DESs over the years has started to influence the operativity of the utility grid and this required the establishment of new requirements and technical regulations to ensure grid stability. What is evident from Al-Shetwi et al. (2020) is that the trend to ensure the integrability of the RESs through the setting of standards and common rules to ensure optimality for all the actors involved, such as manufacturers, grid operators and investors. At the same time, the Authors assess that however this research field is quite unexplored and needs further research and no less important global harmonization and control optimization actions (id.). The integration of DESs can also be easier by combining locally multiple RESs to reach an efficient energy mix (Guo et al., 2018). The energy mix concept resulted also in optimal in the electrification process in the Decarbonization of Central-Western Europe using not only RESs. De Maere d'Aertrycke et al., (2020) indeed demonstrated that mining the central role of electricity to a mix of electricity and green gas offers several advantages in terms of efficiency, flexibility of investment strategies, and robustness with respect to major uncertainties. Another important field of energy transition research that has expanded in these decades is the one dedicated to electric vehicles. Across the globe, Norway represents a forerunner in the field of electromobility, recording using rates higher than aby another country in the world (Bjerkan et al., 2016). This made it possible mainly for purchase and VAT tax exemption. Economic convenience is actually one of the main drivers indeed that could push the transaction toward electric mobility, as assessed by the studies of Plötz et al., (2014) developed in Germany and the one of Priessner et al., (2018) in Austria.

Energy efficiency

The other research branch is the technological advancements focused on the energy efficiency topic. As described before, indeed, the traditional power and distribution systems are constellated by several inefficiencies due mainly to the physics of power flow and the actual design of the large-scale infrastructure. In the literature, there were found two main research topics to optimize power distribution and generation: the application of AI in both traditional and MG systems to optimize power flows and technological advancement in renewable sources' stability and productivity.

Over the past 50 years, the research topic concerning the scheduling of production plants, not only of DESs, has had the opportunity to expand and evolve, finding new tools and methods of predicting demand and subsequent production planning, but only starting from 2015 it has started to become a very active research branch (Gao et al., 2020), thanks also to the fact that in the USA and in Europe then the energy market trend is going toward a more and more competitive market and not more of a monopolistic one, and systems modelling techniques become essential at the systemic level (Foley et al., 2010) to contain costs and be more competitive. Concerning however the DESs, the peer-to-peer technical approaches that can be adapted to enable it can use Game theory, which captures the competition and cooperation between different participants of the P2P market, the auction theory, which captures the interaction of a number of sellers and buyers, Constrained optimization that use mathematical programming under different hard and soft constraints and finally the Blockchain that provides a data structure that can be replicated and shared among the members (Tushar et al., 2020). In any case, DESs require not only optimization methods in the design stage, but also an active management system, different from the traditional static one (Lehtonen and Nye, 2009). An example of an application is one in which IT solutions are accompanied by machine learning (Pallonetto et al., 2019; Antonopoulos et al., 2020), deep learning (China Electric Power Research Institute et al., 2018) and AI models, able to also predict power consumption and optimally manage the power flows. In improving efficiency, the other most important element is the application of ESSs, as already explained in the previous paragraph. The last analysis of the energy efficiency field is the technological advancements in the RESs, to make them more productive and efficient, especially in the field of solar power. For instance, it has been assessed that more than three decades of research in the organic semiconductors field has improved efficiency by 13% (Inganäs, 2018), but also the most recent research field on inorganic perovskites is considered to be one of the most appealing research hotspots in the field of perovskite photovoltaics due to their superior thermal stability compared to their organic-inorganic hybrid counterparts (Xiang and Tress, 2019), both with the use of PCM combined with nanoparticles Al2O3, that allows controlling the inefficiencies due to high-temperature (Abdelrahman et al., 2019; Ali, 2020). To increase the productivity and efficiency of solar panels, the research is also concentrated in the field or concentrating solar power (Islam et al., 2018). These previously listed discoveries are not all the fields of research that in these decades has taken place around the world in the generation and distribution of Solar energy, but thanks to a recent study by Xin et al., (2022) that have demonstrated a negative correlation between technological advancements on these topics and environmental benefits, it can be affirmed that investing in these technologies can actively contribute to reaching the environmental benefits that have been proposed worldwide. Accompanied by the research on solar energy there are also studies on the wind power generation and predictability of the sources (Porté-Agel et al., 2020), biomass, thanks also to the increasing presence estimates worldwide by 56% in the period from 2010 and 2040 (Bajwa et al., 2018) and the expectation of his growth thanks to the growing agricultural production (Perea-Moreno et al., 2019) other than geothermal energy, used by 62 countries in the World that has grown in power installed by from 2015 to 2019 at a rate of 8,73% annually (Lund and Toth, 2021).

2.3 The Renewable Energy Communities (RECs): definition and regulation

Renewable Energy Communities (RECs) are a set of energy users that decides to undertake shared decisions that aim to take decisions concerning their need for electricity, to maximize the benefits of an auto-produced and shared energy, made possible by decentralized energy generation systems and the smart management of energy flows (De Santoli L. 2016).
RECs are the entity by which the energy transition and the SG can take place, passing from a unidirectional power flow to a bi-directional power and information flow. According to the relationships with the electrical system, can be defined two types of ECs: the first is the "on-grid" as a network linked to the public traditional grids and one that is "off-grid", a solution that is typically applied in Developing Countries and in remote communities where the traditional power network does not come (id.), such as Greek islands of Crete and Chalki (Katsaprakakis et al., 2022).

2.3.1 European legal framework

In Europe RECs and self-consumption were promoted with the introduction of the so-called RED-II, as that the Directive 2018/2001/EU that concerned the use of renewable resources, and Directive 2019/994/EU about the common rules on the international electricity market that aims to the integration of the National electricity markets to interconnect also closed circuit that are the energetics islands that nowadays characterizing the European energy market.
However, it is the RED-II (from now *Directive*) that defines the characteristics, the possible normative models, the obligations, and the right of the participants of a REC user. RECs differ from the Citizen Energy Community (CEC) which is defined by the other directive, by the fact that they can use also fossil energy sources. For this reason, these lasts are not treated below because not coherent with the most recent EU directives concerning the energy transition and so with the purposes of this dissertation.
The *Directive* gives primarily the definition of the prosumer as a final user, belonging to a Member State, that generates electricity from renewable resources for his needs, having the possibility to store and sell it with the constraint that this selling activity must not be its primary commercial or professional activity. These entities can also be part of the same building or condominium. The Member State must ensure that prosumers can produce, consume, store, and sell to the grid the surplus generated energy obtaining the appropriate remuneration, maintaining their right and obligation as a final consumer and installing and managing the generation and storage plant jointly and without any additional doubled cost. The Directive

allows also delegates the activities of installing and managing the energy facilities and flows, by a third party, remaining however below the decisions of the users.
The *Directive* doesn't limit to giving only the definition of self-consumer, but also describes the REC, distinguishing it from the latter for a legal and practical perspective, introducing officially this element on the European legal framework. REC is defined as a legal entity settled and participated voluntarily by her shareholders, that manage and are owners of the power facility that must be located in the proximity of the community members. In addition, the regulation poses an important limit to the ratio of the REC, as the fact that these entities are not legitimated to produce financial profits but rather environmental and social benefits for the local communities where it operates.
Can be legitimate members: the physical persons, the companies, and local authorities. The persons who want to join the community are free to participate without any impairment on their rights or duties, except for companies the participation cannot constitute the main professional activity, and the community can participate in the energy market freely without any penalization.
Hence, following this definition, the legislator wants to enlighten the difference between the already note self-consumption concept and the new RECs, which includes a broader concept of sharing energy, in which not only the members of the same palace share their energy, but where actors of a bigger community like a neighbourhood or a small town, share the produced energy in a consumer/prosumer model in which each member can produce, consume or store the energy reaching environmental and economic benefits in a larger scale and in a more aggregate way than the self-consumption scheme.

From Di Silvestre M. L. et al. (2021), although the *Directive* should have been transposed into National legislation, some Nations such as France and Austria acted before, introducing in their legal system the concepts of Collective Self Consumption, as it is possible to see from the following timeline in Figure 2.4.

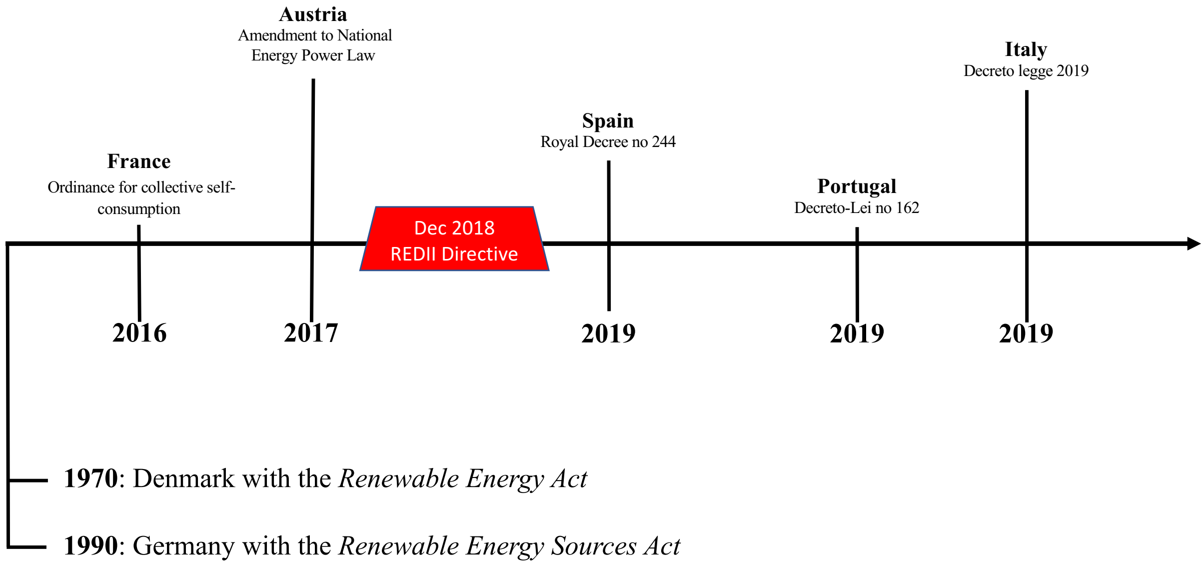


Figure 2.4 - Timeline of European regulation evolution – Personal elaboration

Collective self-consumption was introduced by the French Government in 2016 with Ordinance 1019/2016 which allows building facilities that don't exceed the 100kw power limit that can share their electricity with users that are all linked to the same low-voltage electrical substation (id.). French energy authorities and politicians however remained sceptical about the auto-consumption initiatives since the users are forced to buy from the grid at a price that is 15% higher than normal consumers. Austria instead through the Austrian Green Electricity Act of 2017 introduced the condominium auto-consumption, where the users share instantaneously the energy generated by the photovoltaic modules installed on the roof of the building (id.).

Among the countries that have transposed the *Directive,* there are only Spain, Italy, and Portugal. With Royal Decree 244 of April 2019 and successively with the Decreto-Lei 162/2019 Spain officially introduced the RECs in its legal framework giving a clear definition of self-consumption and RECs, the lasts configured as entities that can store, produce, or sell renewable energy. However, nowadays some details still need clarification such as the definition of the decision-making process for the creation of the community and the territorial extension that can assume (id.).

The fact that only these countries have transposed the *Directive* doesn't mean that the other countries' legal framework doesn't mention concepts like renewable energy or self-consumption but rather does not include the discipline of the RECs that the EU has legislated. This is the case of Germany, which despite it didn't transpose the *Directive*, since early 1990 the German Renewable Energy Sources Act introduced a similar concept of Austrian self-consumption, but almost 20 years before. Later in 2000, were introduced also fixed incentive tariffs for anyone producing renewable energy for 20 years. This pushed many households to install photovoltaic panels and gave impulse to several projects that involved solar and wind power that reached the 40% of total photovoltaic production from community-owned facilities. Denmark is promoting community-owned energy projects since the 1970s, even early than Germany, especially in the field of wind farms. Furthermore, the Danish Renewable Energy Act established that all new wind projects must be owned by at least 20% of the local population, giving to the population the responsibility with the energy service companies, of the production and sharing locally the generated energy (id.).

2.3.2 The Italian legislation of RECs

As happened in Germany and Denmark, some initiatives of RECs were developed in Italy, especially in the northern Regions, already operative since the early 2000s (Barrocco et al. 2020), such as:

- Funes: active since 1921 in Alto Adige with the name of "Società Elettrica Santa Maddalena", fed with three hydro centrals, a photovoltaic facility and two biomass facilities for a total of 5.7MW, made the valley entirely green and an example for other mountain territories.
- Cooperativa Elettrica Gignod: located in Saint Christophe, in the Valle D'Aosta Region. In compliance with the ARERA regulation and of the "testo integrato per le cooperative elettriche storiche" (TICOOP), the generated energy is transferred the exceeding energy to a trader and bought from it by the one that needs it.
- Weforgreen: located in Verona and established in 2010 in Provinces of Lecce and Verona, is composed of three photovoltaic facilities for a total of 3 MW that serves 1.471 domestic users and a mini-hydro facility that serves other 260 houses.
- Cooperativa ènostra: born in Milan in 2014, serves 969 users like households, companies, and third-sector organizations. Its facilities are five plants located in the Cuneo province and another in the town of Sorbolo, for a total of 499kW of power. The community reached a reduction of 60% of the bill costs.

Several companies that before the transposition of the RED-II helped to develop these kinds of initiatives. As reported in Di Silvestre M. L. (2021), in Italy there are Retenergie, Energia Positiva, and ForGreen, which had the role of protagonists in developing RECs projects starting from the new millennium. Retenergia was active since 2008 and developed 13 projects financed mainly by citizen contributions that in exchange received proceeds from the energy sale.

Retenergia in addition merged with the previews cited cooperative ènostra, which was the first electricity supply cooperative in Italy. ForGreen instead is the company that developed the Weforgreen energy community, and it operates in Verona. In 2011 it also started to promote other communities like Energyland, Energia Verde, and WeForGreen Sharing, where in Lecce, implemented a photovoltaic plant of 1MWp.

These examples are obviously not compliant with the *Directive*, however, they are virtuous examples of what auto-consume and energy sharing can provide to a community, especially in terms of energy independence and economic benefits.

The Italian regulation on collective self-consumption and renewable energy communities consists of Article 42-bis, included in the Milleproroghe Decree (converted into law no. 8/2020 on 29 February 2020). The current regulation seeks to provide useful elements for the implementation of European directives functional to the occurrence of the investments present in the objectives established in the National Integrated Energy and Climate Plan (PNIEC) (Barroco F. et al. 2020).

According to the Milleproroghe Decree, Italy defines self-consumption like the Directive 2019/994/EU but differently here the consumer of the same building must share only energy exclusively from renewable resources and the facility can be owned also by ESCos or a third party. Dispositions concerning the RECs instead give to them a no-profit character, forbidding the possibility for ESCos and other energy companies to have the property of the facility, however, they can provide services for the community and benefit from the present fiscal benefits. The Decree established other two main constraints, the first is the limit of the 200 kWp that the facility must not exceed, and the second is that the users of the community must be located under the same low-voltage electricity cabin. However, with the DLgs. 199/2021 the limit was extended to 1MWp, and the users can also belong to the second low-voltage power cabin. Concerning the components of the community, are allowed all types of users such as Municipal Administrations, research and training bodies, religious bodies, third sector and environmental protection bodies as well as local administrations contained in the list of public administrations disclosed by ISTAT that are located in the territories where the community is active and they are also free to leave the community at any moment (id.). It has been established also that the community can use the already existing distribution network and so use forms of virtual self-consumption and shared energy, which is possible only through smart meter technology and other IT communication devices as mentioned in the previous paragraph. The same Decree allows users having already operative facilities to participate in the community if they don’t exceed 30% of the total installed power of the community. It is not indicated which renewable source can be used leaving it to the community to better adapt their energy supply to the best-suited energy sources to be exploited in their territory.

The law 8/2020 established specific incentive tariffs that reward self-consumption, granted by the Gestore Servizi Energetici (GSE), the Institution that manages the Italian energy sector and is in charge of providing incentives for self-consumption and accumulation to users who invest in renewable sources. Thanks to the implementing measures, such as resolution 318/2020 / R / eel of the ARERA (Italian Energy Regulatory Authority) and the Ministerial Decree of 16 September 2020 of the MiSE, has been introduced the parameters functional to quantify and individuate the tariff benefits granted by the GSE. It was defined the produced electricity, as the electricity entered into the grid net of the loss coefficient, the electricity consumed as the one consumed within the grid and the shared electricity for self-consumption defined as the minimum, in each hourly period, between the power generated and fed into the grid by the community plants and the electricity used by all users. Energy is considered shared for immediate self-consumption even if it is taken from storage systems.
An incentive rate has been set to immediately pay for energy that is self-consumed, in order to encourage the adoption of storage systems and the sharing of energy. The system must be installed after 1 March 2020 and so compliant with the Milleproroghe decree, in order to qualify for the incentives. The incentive rate will be established as reported in the table below and, where applicable, will be cumulative with tax deductions.
Viti et al., (2020) confirm the appropriateness of this incentive in increasing the level of self-consumption and accelerating the diffusion of building integrated RESs. A brief resume of the Italian incentives is reported below in Table 2.2.

Shared Energy Valorization	Self-Consumption	Renewable Energy Communities
ARERA Contribution	10 €/MWh	8 €/MWh
MISE incentive	100 €/MWh	110 €/MWh
Sell price	-	60 €/MWh (variable)
Other Incentives	Superbonus 110% that is alternative to the MISE incentive since they are not cumulative	

Table 2.2 – Italian REC Incentives – Viti et al. (2020)

In both cases, the feed-in-premium, as the tariff that is added to the market price of energy in the time considered, is applied for 20 years. With the option of Superbonus 110%, disciplined by the Dlgs. 19 May 2020 n.34, it is possible for those eligible to install photovoltaic plants and storage systems only if they don't participate in any initiative of self-consumption or shared energy. To be eligible, in addition, it must renounce the incentive tariff of the MD of September 16, 2020, but it is possible to reach the 50% contribution in 10 years to recover the installation costs (Di Silvestre M. L. 2021). The presence of these incentives are of vital importance in promoting the BM development of the RECs, as reported in the next paragraph. The Netherlands in fact, to foster RECs spreading, made use of the regulative exemption, however, it didn't provoke the Desiderated effect for the long-term organizational instability and initial organizational costs, that an appropriate regulative framework and state incentives help to overcome (Meitern, 2022).

Also the Regions implemented some specific regulations about RECs. The first one was the Piedmont region with the Regional Law No. 12 of August 3rd, 2018, the second one is Apulia with Regional Law n◦ 45 of August 9, 2019, and the third one was Liguria in 2020 with Regional Law No. 13 of July 6, 2020. These laws have almost the same characteristics, in which the cardinal element is that internally Regions established a Technical Table that supports the creation of RECs with also the role to evaluate and monitor the outcomes of the initiative in the Region (id.). Table 2.6 lists all the successive Regional laws that have been emanated (Roversi et al. 2022).

Region	Regional Law
Abruzzo	17 may 2022, n. 8
Calabria	10 november 2020, n. 25
Campania	29 december 2020, n. 38
Emilia-Romagna	27 may 2022, n. 5
Marche	11 june 2021, n. 10
Veneto	5 july 2022, n. 16
Lombardia	23 february 2022 , n. 2
Valle D'Aosta	Draft Law 74/XVI
Sardegna	Deliberation n. 6/20 of 25.02.2022

Table 2.3 - Regional laws on RECs – Italian Regional Laws

2.4 Literature Review

After an in-depth analysis of the literature, the following paragraphs report the main results of the studies developed in this field which can be grouped into five thematic areas: optimization methods and results, REC membership, REC business models and Transition Management. The research has been developed taking only articles that mainly examine case studies from advanced countries, except for some that have been deemed useful for dealing with some particular aspects. This choice was made because, as mentioned in paragraph 2.1, the electricity grid in developing countries differs greatly from that of developed countries, since in the latter there are already electricity infrastructures, and sometimes even in a great state of obsolescence and too expensive to upgrade. In developing countries, on the other hand, there is sometimes the need to carry out electrification on a large scale or in small communities, building new network infrastructures rather than integrating DER into the electricity grid, as it does not exist. For this reason, the application environment is very different, and therefore the experiences of RECs analyzed in the developing world cannot be considered functional for the purposes of this dissertation.
The rationale of the entire procedure is to evaluate the degree of advancement of the literature in the study of this phenomenon, from which perspectives it has been observed, and the various research tools used in the analyses, in order to subsequently choose the most appropriate one to analyze the case study treated in the chapter 3 and to answer the research questions.

2.4.1 Optimization methods and findings

The technical-economic evaluation of communities of citizens who share ownership of power systems is a topic widely addressed by the literature. The teams that often deal with conceiving an energy community are called to implement conceptualization and optimization processes that lead to maximizing the economic benefits for users and for the aggregator through the use of various technical or supply management levers, or with the aim of optimally designing the dimensions of the infrastructure to minimize the waste of energy due to variations in the flows of REDs and at the same time maximize the social and environmental benefits. Therefore, the studies concerning these issues that have been carried out through the analysis of case studies come also from developing countries as this thematic treat generally the optimization methods that often use informatic tools and procedures that can fit also in developed countries' framework.

Several papers scientifically investigate how to formulate an optimization model to determine the optimal operating strategy to reach the maximum economic benefit from the REC. In accordance with what was reviewed by Tushar et al., (2020), the most used optimization approach in the peer-to-peer field are game theory and Constrained optimization which uses mathematical programming techniques, obviously, with a variety of informatic tools. In this regard, Chen et al. (2013) developed an optimization model using GAMS/PATH, a software specialized in solving non-linear equations (Ferris and Munson, n.d.), that was used to model the microgrid energy management for an initiative in Taiwan. The authors then run a sensitivity analysis to manage the uncertainty of demand and simulate the various alternatives for battery capacity, since it was a project involving wind, photovoltaic, a fuel power generator and a battery device for power storage. However, the shortcoming of this study was to not have a multi-criteria optimization approach that the shortcoming would have jointly minimized carbon dioxide emission and investment costs and energy maximization, as well as the risk management concerning energy demand and supply and the evolution of the future environmental policy. Precisely in this regard, Wang et al. (2020) addressed the optimal decision problem of a DER aggregator to manage the wind, solar and BSS implementing the RTP demand response program. As mentioned in paragraph 2.1, this represents an efficient risk management tool for dealing with the uncertainty about user responsiveness. Indeed, several papers focus mainly on the risk coming from the supply side, as that is the one coming from the unpredictability of the DERs. However, here it is treated also the demand side risk, that in the energy management activity must be carefully handled from the design stage. This risk, if not properly treated, leads to consistent losses for the aggregator, since if the users don't reactively respond to the real-time pricing, it is forced to buy to the electricity spot market the electricity at a cost that is higher compared to the one that in other moments sell to it. For this purpose, the Authors have built up a model, successively applied to a case study developed for the new Thames Valley Vision (UK) using Python and the optimization software Gurobi, in which the aggregator from the historical analysis of the demand side and the integrations of several data concerning the risk of the not reactive action of the users and the RESs unpredictability, constructs a prevision model to program a day ahead the market and the scheduled output power of distributed renewable generations and BES units. The same issue was faced by Pereira et al. (2022) who thanks to the new upgrades of the informatic management platform CECOS, now it is able to record and elaborate energetic flow data to generate precise predictions that allow it to better manage the DERs. Another study developed in China on the optimization process was addressed by Chan et al. (2017) but here the simulation and design of the microgrid have been developed in order to satisfy appropriate KPIs regarding the reduction of energy consumption by 25%, the reduction of carbon emissions by 26% and the generation of renewable energy by 2%, objectives aligned with the targets contained in national and local regulations. Similar methodologies were applied to MCAST case study in Malta (Jately et al., 2021). Even if fossil energy sources are allowed in this case, the interesting fact from the design point of view is that the optimization process of the community has been started aiming to reach specific environmental and energy benefits rather than from the aggregator or final user economic advantages. One of the major outcomes of this study, as the one cited in Wang et al. (2020) and Casalicchio et al. (2022) is the role of demand-side management in shifting the peaks of the energy grid and therefore in the consequent reduction of energy generation and in increasing the financial viability of the initiative. The modelling tools that however are treated are heterogeneous and each one has a specific focus, and for the heterogeneity of the application context, is up to the aggregator to choices the one that fits better (Ringkjøb et al., 2018).

Economics optimization procedures in the Italian literature

From what concerns economic optimization procedures findable in the Italian literature, it is recurrent the use of the Sharpley ratio, a value-based approach used to efficiently distribute the REC revenues among his participants. This would lead to more energy-efficient behaviours and considerable cash flows for the community (Zatti et al., 2021), the financial feasibility and sustainability of the investment for the aggregator (Moncecchi et al., 2020a), and alleviate the risk of the agency problem. It allows, in addition, to program a fair exit value for the users that want to leave the community, indeed according to Italian law, users can leave the community at every moment. It finally helps to establish fair payments for the services provided by the aggregator (Fioriti et al., 2021).

From Moncecchi et al. (2020), collective self-consumption can be modelled as a cooperative game where the game is played respectively by the REC acting as an entity, and each private user. Since the value function is:

$$v(S) = Einjected \cdot EP + Eshared \cdot Inc$$

where S is the coalition of actors participating in the composition, EP is the value of energy injected into the distribution network, corresponding to the market price, while Inc is the incentive value according to Italian regulations. Both the users and the REC (or who made the investment, for instance, the aggregator), want to take advantage of the coalition. The one because made the investment, and the other because of their contractual power since without their presence, whether they are consumers or prosumers, the community would not come true.

Hence, Shapley's value is nothing more than the fairest payoff that has to be assigned to each player. To comprehend better how it is computed, his formula is reported below:

$$\Phi_i(v) = \sum_{S \subseteq N \setminus \{i\}} \frac{|S|!(n-|S|-1)!}{n!}(v(S \cup \{i\}) - v(S))$$

where the second factor is the marginal contribution of player i in the coalition S is weighted for the first factor that considers the possible orders in which player i can join the coalition. In this way is set up a distribution rule in which the revenues of the community are distributed fairly, one that is demonstrated to be more efficient in terms of self-consume, environmental and aggregator and community members' remuneration (Fioriti et al. 2021).

How the Italian incentive system shapes REC's design

Concerning the Italian incentive system, shared energy remuneration leads to optimal portfolio sized on the users' demand, while for instance, an incentive on produced energy leads to an oversized production capacity (Moncecchi et al., 2020). This could indicate that the legislator and ARERA seem that fully meets the objectives indicated by the European directive of reference and by its transposition. However, this type of incentive leads to some distortions (Fioriti et al. 2021) since it rewards the sharing of energy and not its self-consumption. This would seem positive for several reasons, however, dropped into reality it could push those who design the REC to create systems that are not perfectly efficient from an energy point of view (id.). For example, those who design the REC in the presence of a BSS, which has been shown to have a positive impact on the NPV (Keck and Lenzen, 2021), in terms of energy self-sufficiency of the community (Moncecchi et al., 2020), and in economic savings for the users (Bahloul et al., 2022) would be encouraged to provide a centralized energy storage system, so as to increase the amount of energy exchanged between the users of the community. From a technical point of view, this would cause important losses in terms of energy dispersion as the point of withdrawal and the point of consumption of the same are separated. Therefore, the choice that would result from an engineering point of view is to equip each prosumer with his own storage device, to the detriment of the potential economic benefit deriving from the incentive.

Among the other Italian initiatives is the REC of Berchidda. Ghiani et al., (2019) used the HOMER simulation tool to optimally design the REC from the point of view of sizing, energy management and economic performance. In addition to this, there are also other initiatives addressed by the literature as one of the first REC in Italy by Magliano Alpi (Olivero et al.

2021), but to find examples of REC present on Italian territory and therefore consistent with the transposition of the European directive on which impacts can occur, we will have to wait a little longer, as the regulatory framework is rapidly evolving and has not yet allowed for scientific evaluations of the ex-post results on cases that are already operational.

As it is evident from the previously treated arguments, optimization processes are primarily concerned with three areas of intervention, such as the complementarity between the generation and demand of the prosumers, the criteria by which the revenues are divided among the participants and the supply and demand management. However, these three topics must not be handled by the aggregator with the same importance in order to optimize the economic benefits of the REC. Volpato et al. (2022), developed a model using a Mixed-Integer Linear Programming strategy to identify how these weigh in achieving the objectives set. The outcomes show that complementarity reduces the cost by around 15-20%, a fair cost allocation among the REC members reduces the bills of the prosumers using renewable sources by 20-30% compared to those who use dispatchable sources, and price-based programs could low the REC costs even beyond the 50%. These results show that in the presence of state incentives and Price-based demand response programs, RECs allow for reaching higher economic benefits than CEC, which allow the use of fossil energy sources.

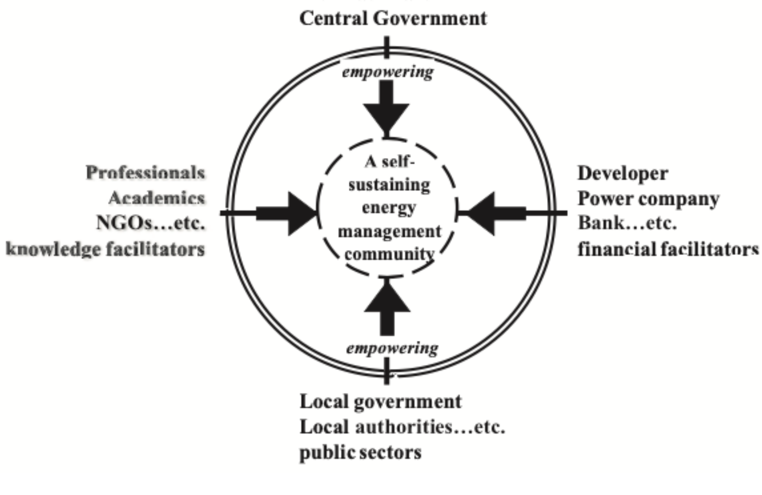
2.4.2 REC's membership

A key success factor of a REC is the participation of the local population (Ryszawska et al., 2021). Concerning this topic, various research assesses the role of the engagement process, around which rotates the constitution and then the activity of the REC. Barnett et al. (2012) have demonstrated initiatives must address some issues that are a source of public concern, as well as the necessity for those who design the community to include in the specifics also what are the main aspects and values to be considered important for stakeholders. This is only possible through an effective population engagement and involvement process. This section first examines which were the main involvement processes applied to the case studies of renewable energy and RECs available in the literature and which actors took charge of carrying out these initiatives, and secondly which are the main drivers from the point of view. in terms of values and attitudes that push users to participate in the REC and more generally when there are initiatives of large renewable energy plants that are built in close proximity to users.

Engagement process

In the literature, there was widely treated the role of social acceptance of large-scale renewable plants. Garmendia and Stagl (2010) affirm that social learning programs, organized with workshops about environmental issues help the population address the complexity and uncertainty of the transaction to sustainability, especially if they are also properly informed before the workshop and through the use of “key influencers” (Heaslip et al., 2016). Successively people are more inclined to set up a constructive dialogue and find new compromises concerning initiatives which provide the commitment to participate in common actions or institutional change, categories in which RECs can fall. Jank (2017) also sustains that the energy transition has to start from the local level, but in practice often municipal energy planning provides only a theoretical scheme for the whole city, regardless of the specificity of the need at the neighbourhood or district level, that must be taken into account (Barnett et al., 2012). For this reason, the Authors suggested that a two-fold approach of “Urban Energy Planning” and “Local Energy Planning” can be the solution to ensure that the carbon emission reduction targets of the city would be achieved in a coordinated and organic way and in the same time allows focusing on the distinctive elements and needs of each community with the appropriate engagement process tools. Only a few cities have applied this solution successfully, like Aarhus in Denmark, Heidelberg in Germany, and Växjö in Sweden. The need for a radical involvement of the local community in RECs initiatives is again evident from the Greek Islands case, studied by Katsaprakakis et al. (2022). Greece has started to implement the RECs having a poor energy policy and disarticulated legal framework, which created opportunities to build large-scale projects RESs plants in Greek islands, pushed also by the need to cover their power needs and to their solar and wind potential. This provoked a common negative public opinion sentiment toward these projects. However, thanks to the support of the Clean Energy for EU Islands Secretariat and the examples of some pioneering initiatives of Sifnos and Crete, has been created a sense of shared knowledge of the initiative that pushed the local population to participate and improve the new proposed initiatives, enthusiasts also from the possibility to replicate the successful solutions developed in other close and already known territories. Also, the studies of Lienhoop (2018), van der Schoor and Scholtens (2015), Yildiz et al. (2015) and Musall and Kuik (2011) and the Italian Tricarico (2021) underline the important role of a shared decision-making process and continued communication among the stakeholders, in increasing social acceptance of large-scale green energy infrastructures. However, knowledge sharing, especially at the inter-project level and with externals sometimes finds several barriers, such as the lack of interest in external knowledge sharing and organizational barriers, that could represent an obstacle to the transition to the implementation of energy transition (Evers and Chappin, 2020).

Karami and Madlener (2022) analyzed a design process developed in Germany by which a REC is being designed by a third party starting however from the community households' beliefs and preferences. This represents a top-down approach that anyway enlightens the need for energy companies and utilities in changing their business model, adapting even more the new investments on the network to the need of the local consumers and prosumers. This new way to interpret the electricity market is becoming a part of the core business of these companies, that are going toward a more consumer and prosumer-centric approach and enabling a multi-directional value chain. There are also cases, however, where the REC project is wanted in first person by the local population, as reported in the case of Freiamt, a rural community located in the Black Forest, in Germany (Li et al., 2013). The willingness shown by the REC residents in wanting this initiative within their community reveals a bottom-up approach in the consensus and design of the same. However, the authors underline that this approach was only possible thanks to the intrinsic characteristics of the people of that territory, who are known to be endowed with a great spirit of independence and freedom. However, it is demonstrated that the RECs that are born in this way are more resilient and sustainable in the long term. However, the authors do not exclude that even top-down approaches in certain contexts may be more profitable. The bottom-up approach, however, must not be understood as a closed system in which those who started the process act independently but rather as a tool in which users have already internalized the will to participate in the community which is then inserted in any case in a very broad system of relations functional to the development and management of the REC, as it is possible to see from the Figure 2.4.1.



The networking activity between the various stakeholders that were called to participate and collaborate in the initiative, like municipal officers, project developers, technology market actors and citizens, was one of the key factors of the success of the initiative. A different issue is whether a community has to decide who and how many participants can join the community, both before and after its constitution. Mustika et al. (2022) provide a heuristic method to fairly assess who is more deserving to participate in the community, or who with his energy consumption and/or production profile, provides a greater benefit to the community in terms of minimizing the demand-supply energy mismatching and maximizing self -consumption.

Hence in this section is clear the role of the literature in assessing the role of the involvement of the local population in the decision-making processes of construction of renewable large-scale infrastructure in the local population's acceptance of those initiatives. It has also addressed the importance of the engagement process in the formation of the RECs and so the central role of the aggregator to link and make dialogue among the various stakeholders, to create a multi-directional and shared value chain. Certainly, a bottom-up approach in the formation of a REC acts as a catalyst to the formation of the REC, however also a top-down approach, for instance on a private or municipal initiative, could create the same outcome whether the various stakeholders are properly considered, and the initiative goes to meet the specific needs of the community.

Citizen engagement drivers

The participants of the RECs join the community according to their values and interest, which sometimes do not exactly match the values for which the recs were designed and so it is appropriate to investigate their roles in REC adherence and the users' engagement process. In the literature, a variety of papers are present that assessed which were the motives that pushed people to want to join and on the contrary which are the possible obstacles that negatively influence the perceptions of single individuals toward these initiatives.

From the literature, it emerged that the motives that push RECs participation and social acceptance of RESs plants are:

- Economic benefits/cost reduction, amount, and fairness
- Community benefits
- Health risk perception (for instance of wind turbines)
- Environmental concern
- Community pride sentiment

From the literature emerges that economic benefits seem to be the first motive for social acceptance of large-scale energy infrastructure and of adherence to the local community (Baxter et al., 2013) (Heuninckx et al., 2022) (Li et al., 2013) (Karami and Madlener, 2022) (Kaschub et al., 2016) (Dóci, 2015). However, it is also true that those benefits play a decisive role only if they are clearly quantified and so that the population is aware of the impact of the initiative, as explained by Caporale and De Lucia (2015) concerning a wind plant social acceptance in Apulia. Despite the amount of assessment in which the hedonistic scope is prevalent, there were also initiatives in which the community benefits played an important role in REC participation (Heuninckx et al., 2022) (Baxter et al., 2013), united also at the citizen pride in being energetically independent of the external (Dóci, 2015), especially in remote and socially closed communities (Li et al., 2013). Last but not least environmental concerns push people toward REC participation (Conradie et al., 2021) (Heuninckx et al., 2022) (Dóci, 2015).
Furthermore, Dóci (2015) has demonstrated that aggregation comes in communities where the level of trust is relatively high but the Authors retain that a feed-in tariff could anyway act effectively making leverage on the cost-saving driver guaranteed by the incentive of the State.

From empirical ex-post-developed assessments, there were found that RECs in most cases provide the aforementioned outcomes. Van der Waal, (2020) through a change mapping approach, which is an impact assessment methodology, assessed that the most impactful benefit reached by the Orcadian community, in Scotland, was the economic benefits, in accordance with the earlier stated. Secondly were found local economic development, social cohesion and knowledge and skill development. Algarvio (2021) have proven great outcomes from a Portuguese REC composed of 312 consumers, 38 solar PVs, 227 wind farms and 40 hydroelectric power plants active in the period from 2011 to 2013. It has been assessed that REC consumers can decrease their energy costs from 54% to 76% and that for a prosumer is more convenient to be part of the REC since it would save 24% against 16% as an alone self-consumer. In addition, it has been evaluated that if the REC should be integrated with the existing RES plants will increase the savings by an additional 7% to 14%.
Kaiser et al. (2022) however found slightly different outcomes relative to the solidarity-oriented REC of San Giovanni Teduccio (Naples). Environmental, social, and economical outcomes were evaluated according to Social Life Cycle Assessment (s-LCA) (UNEP 2020) and Life Cycle Assessment (LCA). The first one used also in another Italian paper by Rossi et al. (2021), accounts for the social impacts of a particular initiative (Benoît Norris, C. et al. 2020) and was implemented with the use of submitted questionnaires to the involved households and various stakeholders, while the second addresses the environmental impact of the REC from a life cycle

perspective (Klöpffer, 1997). The results enlighten that in this kind of initiative the economic motive passes into the background since from the families' point of view the initiative produced a high degree of social cohesion and an improvement in the condition of energy poverty. LCA support what was discovered by the s-LCA, attributing to the self-consumption the role of an effective tool to achieve energy justice (Jenkins et al., 2016) and environmental benefits. The fact that in a similar initiative the economic motive is not central, it is however coherent with the previous consideration about the importance to address the specific need of a community and not all the communities have the same beliefs and values. Here the fact that the REC is born to satisfy social and energy justice purposes, is perfectly coherent with the research results.

2.4.3 REC Business models

One of the branches of literature concerning RECs is that relating to the various types of applicable business models, to obtain those economic and environmental benefits, and make the activity economically sustainable over time. Iazzolino et al. (2022) found the main barriers related to the implementation of the community, that are of technological, socioeconomic, environmental, and institutional nature. The main aspects are resumed in the following table.

Technological	Socioeconomical	Environmental	Institutional
Load fluctuation of the RESs	User awareness of their role in the electricity market	Awareness of the climate change issues and the objectives to be achieved	Lack of trust of the stakeholders
Scarce energy efficiency	Lack of proactive role of the Consumers	Incentives linked to the environmental performances	Energy democracy
High investment cost of ESS	Economic incentives to support the investments	Recycling issues of the RESs and the ESSs	Shared Public-Private participation

Energy load matching problem	Revenues sharing fairness between who make the investment and who not	Population acceptance of the RESs and the possible private spaces required to install them	Lack of the suitable legislation, incentives and support schemes
Reliability of the network			Management difficulties of the users and governance issues of the local distribution network
Non easy predicable demand			

Table 2.4 – Issues of the RECs business models - From Iazzolino et al. (2022)

Types of Business models

Another interesting study developed by F.G. Reis et al. (2021) reported an analysis of the present Business models present in the European context. The models were analyzed through the Canvas framework methodology and eight types of different BM archetypes have been found.

- Energy cooperatives

  This category is the most common in the European continent that counting almost 2400 projects by which more than 800 were reported only in Germany. In these initiatives, a variety of funding sources and organizational forms can be found, however, the main characteristics are that are bottom-up initiatives based on voluntary participation and democratic control. They can be constituted as companies or non-profit organizations, the first used in cases where there is the necessity to make large investments and the second to address a specific energy need of a community with the profits reinvested in among the participants. Some communities of this type can also benefit from the role of the municipalities in providing extra technical assistance and funding. Municipal energy cooperatives were developed mainly in countries like Germany, Denmark, France and Spain, countries where the municipalities play an important role in energy supply and distribution network activities.

- Community prosumerism

  They are communities typically created by prosumers, which assume the role of decision-makers, investors, and customers. In this REC, each participant is supplied with an ESS and it is responsible for the need of the community and can also sell its electricity within the community benefiting from the medium-high voltage network use of system tariffs. Transactions between the community and the external consumers are usually recorded by the local grid controller, which can assume a passive role in recording only the transactions or can act actively in inducing the participants to adapt theirs consumes in order to trade at favourable conditions with the external network. Benefits from this type of initiative are the minor costs on the bill and the sell revenues, that can be divided among the participants or reinvested in the community.

- Local energy market
  These are typically founded by prosumer-driven communities with the objective to minimize the energy trading with the external. These sometimes can be in different areas, not close each to other, for this reason often in this type of BM, are created community virtual power plants or prosumer community groups. Firsts are less spread in Europe due to the lack of appropriate regulation. In fact, the local community can be more attractive to prosumers, that can exchange their surpluses within the LV distribution network without facing any additional distribution fees.

- Community collective generation
  Is the initiative that is based on shared generation and storage systems installed on the same multiple-tenancy building. Usually, the investments are made by the owners of the building. This type of initiative is found in Austria and Bulgaria, in which surplus sales are however not allowed because of an absent regulatory framework.

- Third party-sponsored communities
  Also, the energy private sector actors are seeing at the REC as a source of revenues move to the develoment of appropriate BM that would fit their investment portfolios. In fact, several technologies and energy utility companies have implemented many projects in which through long-term PPAs signed with the community, they provide REC's energy infrastructure and management in exchange for cashing a part of the revenues generated in exchange for the bearement of the risk of the investment. The governance of the facility is left to the private but coordinated with the local community, which is properly involved in the decision-making process. Despite the central role of the utility company in running the infrastructure, the nonprofit local organizations are entrusted the role to address specific

local issues, allocating the proper RECs revenue to alleviate, for instance, energy poverty and poor housing conditions.

- Community flexibility aggregation

  These are BMs that involve high degrees of technology involvement due to the fact that involve the participation of large-scale energy generation facilities, like the industrial one, or a group of Local RECs that jointly collaborate to then make offers to provide balancing, ancillary or reserve services to the market allowing the small case users to enter actively on the energy market. Aggregators are usually in charge to contract to one side with the users that must provide a certain degree of their consumes flexibility in exchange for favourable bills, and to the other with the network system operator. The degree of flexibility of the users can be assured through the already cited price-based programs that signal the proper moment in which is optimal to consume or to not consume or the members can also allow the external operator to control their appliances during peak periods through direct load control. The regulatory framework has a key role in enabling this aggregation since can lead the existing energy companies to change their business models, due to the fact that RECs will perspectively (2024) create coordinated clusters and assume an active role in the power network, creating "Virtual Energy Companies", also thank to ancillary services that nowadays are provided by few large energy corporations (Olivero S. 2022). (Olivero S. 2022).

- E-mobility cooperatives

  This BM involves several actors, like families, SMEs, public bodies etc, to provide car-sharing or carpooling services that can use the community assets. ESSs (Energy storage systems) can play an important role in these communities also exploiting the batteries of cars as "distributed storage capacity" and so providing ancillaries services to the grid balancing the same during load fluctuations (Olivero S. 2022). There is also the possibility to implement hybrid RECs in which energy mobility services can be provided through the energy generated exactly from the REC members. These cooperatives are however profit oriented since they usually involve energy suppliers, technology providers and distribution operators, and user fees are applied. These BMs of the high degree of technology involved and the lack of regulation regarding the management of ancillary services of grid-to-vehicle and vehicle-to-grid transactions, are still difficult to implement and are not yet very present in the European market.

- Community ESCo

These Communities are defined by the Author as “communities of place and interest” since they aim to provide not only the sharing or the construction of energy generation facilities, with the subsequent energy supply, but also energy efficiency (EE) interventions, both done by an ESCo that traditionally do these interventions but not at the community level. Typical ESCo's BM differs from other energy companies because its revenues usually come from the reached energy saving of the customers. These societies apply a variety of BMs that provide different services, for instance, solar renewable energy as a service that uses photovoltaic plants to provide electricity and investments and O&M services, or the providing of building heat that uses a district heating infrastructure. Both can be regulated by an EPC to ensure users an agreed level of economic saving or internal temperature comfort. Like the third-party local communities, the profit derived from the energy savings and the sale of energy can be divided among the participants of the REC and the ESCo for the remuneration of the investments. Since the property of the plants is of ESCo, the government of the RECs is in the hand of the same, but with a high degree of participation of the community in the decision-making process. Since the ESCos are present in all the Member States, it is auspicial a large application of these BMs.

An example of community ESCo can be found in the paper of Iazzolino et al., (2022) which is an elaboration of a proposed model by Tang et al. (see Iazzolino et al., 2022) that previewed the sharing business model, as a community divided into clusters where each one shares their energy within the community. Each user is provided by an ESS. The proposed business model was also analyzed following the Canvas framework, to understand the value created and to comprehend the complexity of the business's operations. A Canvas analysis example for a community energy system is reported in Figure 2.5.

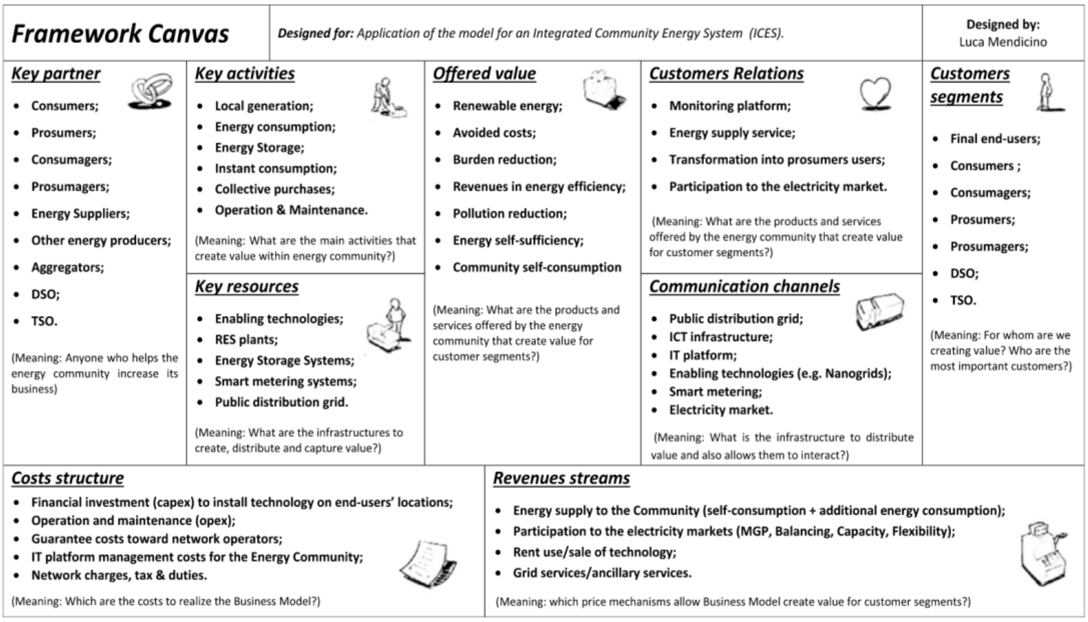


Figure 2.5 – Example of Canvas model - taken from Iazzolino et al., 2022

In this BM, the members are consumers, prosumers with the technology provided by the aggregator, Prosumers with PV generation plant to which the aggregator provides enabling technology, and Prosumers owners of all enabling technology. Here the aggregator, which is supposed to be an ESCo plays a central role in setting up the plants and managing the REC. indeed it is entitled to maintain and set up contracts with the other stakeholders such as:

- Consumers
- Producers and Prosumers that could require investments and an O&M contract
- Financial Institutions
- State concerning the required Taxes to be paid
- National market operators
- Network operators

The simulation however demonstrates that the clusterization of the users must be done smartly according to the specific energy profile and that initiatives developed locally and of the smallest dimensions tend to be less profit-oriented and, on the contrary, the bigger ones require also to include financial benefits to enhance more participation and large-scale initiative. McGovern (2021) formulated the BM of a Civic Energy Community (CEC). It is defined as an organization that shares the renewable energy generated by both users and municipal plants. Authors use a civic energy process model derived from the Civic Energy Cycle, as a scheme used in structuring these kinds of initiatives, that from the literature are very difficult to develop for the variety of interests of the multiple stakeholders involved.

About Italian context, Cielo et al. (2021) tested three alternatives of BMs that can be applicable to the Italian context using the experience of Monticello D'Alba residential REC as a case study. The first one previewed that the entire investment was done by the community itself, the second one where a technological company acted as a technical partner that acquire and manage the facilities withholding all profits, while an intermediate case in which the same shares part of the profits with the members of the REC. The simulation applied to the case of Monticello D'Alba lead to positive outcomes in all the configurations, reaching an IRR greater of 11% and emission reduction of close to 45%.

Network management

Planko et al. (2017) through a multiple case study analysis developed in the Dutch smart grid sectors presented the main key factors of an important aspect that from now it has been neglected, as network management in a new business field, as the RECs are since they have these three characteristics (Möller, K., & Halinen, A. 1999, see Planko et al. 2017):

1) They aim to develop new services, products, or processes for the community
2) Develop new technologies designed to accelerate market construction influencing public opinion
3) Provide new viable business applications to technologies that are already present on the market but used in other filed of application.

The authors developed a comparative analysis with network management literature and the application of the system-building network of a smart grid. What has been found is that contrary to what is assessed by the literature, some networks have used member reduction to align the network goal defined ex-ante, coherently to what has been assessed in paragraphs 2.4.1. Another point that goes in contrast with the network literature is the fact that trust level is reached from previous collaboration, however, in analyzed cases, it comes from the selection of a specific component to be entrusted with a representative mandate, rather than choosing the associated companies. The elements in which instead the literature and the practice agree are the quality of the project manager and the definition of proper measures of evaluation of its results and the effectiveness of a democratic decision-making process.

Public-private partnerships

Similar issues in implementing a REC funded by Iazzolino et al. (2022), were found also by Xue et al., (2021) in Norway, which proposes Public-private-people partnerships (PPPP) to solve them. The most important solutions that the authors proposed are:

- Co-investment solutions

  In which investors are taken from the private, public, and also users. The major benefits coming from this solution are the facilitation of the financing process, the sharing of the responsibility of some choices reducing the risk for the private and the public party and enabling new operative solutions through a bottom-up approach. This solution is also present in the consumer stock ownership plans business model which allows reducing transaction costs involving also the users to invest in an aggregate way (Lowitzsch, 2019).

- Information sharing platforms

  IT platforms both online and offline information tools are required to ensure knowledge sharing for all the stakeholders involved since one of the important issues in the RECs is the lack of awareness of the citizens and the lack of communication among the private sector operators. The practical communication tools that can be developed are online platforms such as mobile applications that help users to understand the possible benefits of the RESs and some physical initiatives such as workshops, meetings, advertising and surveys.

- Creation of new incentives policies

  New incentives created by the public party such as the Italian feed-in tariff, help public sector to involve the users and break down the private sector barriers, the evaluation by the public sector of the impact of these incentives and finally provide more support to the private sector in implementing the RECs. In the EU context, this was already present in the EU legislation with the RED II and the transposition of the directive by the various member states.

Literature then focus on the evaluation tools that can be implemented to a PPP project, that aim to evaluate the environmental benefits reached by the REC identifying the appropriate key influence factor to assess the sustainability of the microgrid (Lu et al., 2021). However, this focus is mainly on technicalities that are not useful for this dissertation.

Another two papers found in the literature treat the PPP applied to the electricity field. The first of Koliba et al., (2014) use a case study of Vermont large-scale application of a smart grid. The authors here found through a Salience Complexity model, that PPP addresses the issues of the application of this infrastructure as the lack of adequate policy support, and that this type of

application of new energy technologies will give rise to new forms of business-consumer relationships, thanks also to the wide use that consumers make of energy devices including smart-homes and functional systems for electric mobility, which are strictly related to the implementation of smart grid systems.
The second paper of Gharieh and Jafari, (n.d.) reports instead a modelization of a Design, building, operating, and maintaining (DBOM) PPP project to be developed in New Jersey. The financing model is represented by the possibility of private to access to an initial senior debt opportunity through the emission of zero-coupon municipal bonds, and then the possibility of annual junior debt, resulting in both public and private considerable profit gains

2.4.4 Transition Management

In this section, the topic of the REC is treated as a disruptive innovation, defined by Thomond and Lettice (2002) as a rapid change in a business field that represents a discontinuity of the natural evolution of the innovation. The literature review here will touch on the consequences of the company BM change to adapt it to this new innovation, the methodologies used by authors in evaluating how the stakeholders participate in the value co-creation process and finally how transition management faces the managerial problem of the REC's business initiative.

New technologies are transforming how energy companies act, from the generation to the distribution business field. Smart grid systems, photovoltaic and ESSs represent some of these disruptive innovations that require specific BM to develop in order to commercialize and create a shared value chain along far all the actors involved. The way in which energy companies have to redesign their BMs to address the upcoming population needs was studied by Mahzouni (2019) Bhatti and Danilovic (2018). The authors demonstrated that the companies that have not modified their BM and integrated it with the available new smart grid technologies have gone out of business. More specifically, the services that they must be able to provide thanks to this technology are the integration of RES with the SG, electric vehicle services, and demand response services that make energy firms able to provide gains for their consumers. These new implementations are a win-win initiative since the companies increase their profits by integrating the RES with the SG and the consumers can reach cost savings because the production costs would reduce significantly.

Ryszawska et al., (2021) using the DART model (Dialogue, Access, Risk, Transparency), often used to define and classify value co-creation behaviour in scientific research (Mazur and Zaborek, 2014), to assess using a housing cooperative initiative in Poland, how the various stakeholders acted to implement a such initiative to then formulated some recommendations for the implementation of future potential communities.
Another method to assess value co-creation was used by Mihailova et al. (2022) that applied the stakeholder theory approach, which studies the interconnections between business and the customers, suppliers, investors, employees, or others that have some interest in the organization. This methodology, applied to the case of Schoonschip, a REC of houseboats located in the Johan van Hasselt Canal in the north of Amsterdam, has the same objective as the previous one but acts as mapping in a polycentric setting what are the dynamics that lead to value co-creation and how the BM integrate the various stakeholders' objectives and the various roles that citizen can assume in the organization. Vernay and Sebi (2020) for the same purpose, used the ecosystem theory, to analyze the differences between the French and Dutch REC ecosystems, to find their differences and similarities. They found three levels of comparison which are:

- Comparing RECs at the individual level
- Ecosystem analysis, as that lobbying activity, networking and knowledge sharing, financing, and operational and technical support
- Local capacity builders that acted as local catalyzers

A third methodology that proposes to create a managerial guide concerning the creation of the REC, comes from transition management (TM). Lode et al. (2021) indeed applied a multi-actor multi-criteria analysis (MAMCA), a participative multi-criteria decision method, to a case study in the Netherlands, in order to provide an analysis of the application of power relations, the political sphere, sustainability conceptualization and guidance of transitions of a REC project evaluation. TM is a recent field of research that aims to unify insights from different science areas, such as innovation studies, sociology and environmental science with the objective to influence and guide the speed and the direction of the changes in these systems (Loorbach et al., 2015). Lode et al. (2021), applying MAMCA within TM and the case study of the Netherlands, it was possible to display the criteria of the Distribution System Operator (DSO), which represents a powerful stakeholder, but also of the scarcely represented stakeholders, such as final consumers, and then integrating them effectively in the engagement process of the community, in order to develop a standardized and replicable approach for future initiatives.

The outcomes of the analysis enlighten a positive attitude toward the REC compared to other options, and the need to structure the initiative following stakeholders' point of view only after having instructed and educated them about the initiative.

Chapter 3
Case Study and the Multi-Actor Multi-Criteria Analysis

This chapter is the central part of this dissertation. After introducing the topic of Public Private Partnerships and Renewable Energy Communities, framed both in the Italian and European context, The first example of REC in PPP present in Italy is reported and suitably analyzed in order to answer the research question. This is the case of the initiative born indicatively in July 2021 in the Municipality of Montevarchi (Martini S. C. 2022), part of the Province of Arezzo. The initiative was born following the establishment by the Municipality of Montevarchi and its Mayor Martini Chiassai Silvia (2022) of the "Commissione Futura", an initiative attended by most of the industrial excellence of the area, such as Prada and Zucchetti Centro Sistemi. The commission was created with the aim of planning and programming the initiatives to be implemented in the Municipality of Montevarchi in a long-term perspective, and the REC is one of the proposals put forward by the President of Confindustria Toscana Sud as well as the president of Zucchetti Centro Sistemi. The state of the art of initiative, however, is still in the early stage. In fact, it is not yet operational and not even legally constituted, but to date, only the publication of the municipality carried out on 22/08/22, of the proposed promoter advanced by the temporary association of companies Green Wolf Srl-Gruppo Simtel Srl. To understand how an initiative so early and not even under construction can be scientifically analyzed and therefore be relevant from a scientific point of view, the literature review, presented in the second chapter has been fundamental, which made it possible to understand how it could be tackled following the case study methodology. The multi-actor multi-criteria analysis (MAMCA) was useful for this purpose, which found application in the works of Lode et al., (2021) and Lode et al., (2022), in which, however, it was used only for descriptive purpose or to evaluate whether the REC is an optimal solution to implement with reference to the current situation. In this thesis, instead, it will be applied to evaluate if and how the PPP in a REC project faces the different interests of the main stakeholders of the territory. The possible outcomes are therefore interesting because the analysis is not merely descriptive of the scenario in which the interests and objectives of local stakeholders are detected and extrapolated with an ecosystem perspective, as in Vernay and Sebi (2020), but here the role of PPP applied in the REC field, allowing to inspect if the initiative of the REC of Montevarchi, developed in PPP, allows satisfying, and in which degree, the interests at stake, both of the Municipality and the proponent.

The methodology could be applied effectively in the field of TM, using it as an effective tool to find solutions that involve all the stakeholders' interests ex-ante. This is not however the

purpose of this dissertation since it goes to evaluate a project that is already present, but it has been useful to report also some concepts of this research branch since the case of Motevarchi presents however some similarities with that discipline in the emergence of the initiative and further inputs to develop further research and practices.
In its initial part, the chapter provides information on the Montevarchi initiative, found in the tender documents available on the Municipality's website. Secondly, the methodology was introduced, alongside the scope of the TM and finally the analysis carried out applied to the case study is reported, complete with the results that this has produced.

3.1 Case Study: The Renewable Energy Community in PPP of the Town of Montevarchi

As mentioned above, the descriptive information relating to the Montevarchi REC case is reported in the following subparagraphs. The information is organized according to the order of the tender documentation available on the website of the Municipality of Montevarchi. We will begin by providing a brief description of the technical feasibility of the project and how this has been adapted to the context of the municipality of Montevarchi. The part relating to the administrative juridical regime will then follow, which will regulate the relations between the various actors of the project. This section is also relevant for the purposes of the reapplication of the legal-administrative model, which the Union of Italian Provinces has created, and which is awaiting approval by the ARERA in order to make it legitimate for the purposes of using the incentive and therefore for applicability in municipalities throughout Italy (Martini S. C. 2022). Finally, the most important economic/financial indicators present in the Economic and Financial Plan will be reported.
From the interview with Green Wolf Srl (2022), it emerged that all the technical, legal and financial modelling of the REC is done by them, while the other proponent, Gruppo Sim Tel, was functional for commercial purposes since it is part of the territory.

3.1.1 Project of technical and economic feasibility and service and management

Territory and Optimization Model
The municipality of Montevarchi is located in the province of Arezzo, in Tuscany. It has 24,399 inhabitants distributed over an area of 56.75 sq km and is located in climate zone D. Despite its altitude being 144 meters above sea level, the area is flat and exposed to sunlight for several hours a day.

The records state that in a REC initiative the plant capacity can be much higher than physical self-consumption and metered-spot schemes, however, this is only true if only the maximization of self-consumption is taken into consideration. In the case of a REC, this paradigm is transferred to the community level, therefore maximization must take place within the whole community.

Green Wolf Srl has applied a simulation model to predict the optimal power of the plants and the optimal number of users that the community can have in order to optimize community self-consumption. The estimates of the consumption profile of residential users were obtained from the GSE study "Analysis and evolution over the years of the load curves of domestic customers" by Maggiore S. et al., and for commercial users from the indications contained in another document published by ENEA, entitled "Benchmark of energy consumption of office buildings in Italy". Combining the information from these two studies, it was possible to infer the land load profile. The production profile of the photovoltaic plants is instead taken from the PVGIS-SARAH database, considering the average of the values recorded from 2005 to 2016. The model also envisaged a possible accumulation system to be implemented, but at least until the REC is expanded, the choice was made to act on the consumption side of the curve rather than on the supply side, which remains fixed at the power of 1MW and without ESSs.

Plants characteristics

Considering the publicly available surfaces, it has been selected twenty-three rooftops to install the plants that are resumed in the following table, also indicating the building name and use destination, the installed PV modules, the total power of the plant and the estimated annual produced energy.

No.	**Building**	**Use Destination**	**Surface smq**	**Number of Modules**	**Power of the plant (kW)**	**Annual energy of the plant (kWh)**
1	Scuola Secondaria I Grado Petrarca	School	651	177	53	70.092
2	Scuola Primaria/infanzia Isidoro del Lungo	School	449	122	37	43.920
3	Scuola Primaria/infanzia Mazzini	School	794	216	65	84.240
4	Scuola Secondaria I grado Mochi	School	996	271	81	91.056
5	Liceo Artistico	School	316	86	26	32.250

6	Scuola Primaria L. da Vinci	School	1.026	279	84	108.636
7	Scuola Primaria Don Milani	School	1.191	324	98	121.500
8	Scuola Infanzia staccia Buratta	School	419	114	34	42.750
9	Asilo Nido la Farfalla	School	265	72	22	28.512
10	Liceo Scientifico Vasarri	School	764	208	62	84.240
11	Palazzetto dello Sport	Gym	2.651	721	216	281.190
12	Centro Documentazione	Offices	143	39	12	13.455
13	Scuola primaria Giotto	School	309	84	25	32.256
14	Scuola dell'infanzia II Prato	School	173	47	14	18.471
15	Asilo nido la Coccinella	School	382	104	31	32.760
16	Scuola dell'infanzia Vittorio Emanuele II	School	59	16	5	6.336
17	Scuola Infanzia Pestello	School	199	54	16	20.088
18	URP Levane – Piccolo Principe	Offices	88	24	7	9.144
19	Centro Culturale La Ginestra	Cultural Center	184	50	50	19.500
20	Scuola Levanella	School	324	88	26	33.000
21	Cimitero Comunale A	Cemetery	533	145	44	50.025
22	Cimitero Comunale B	Cemetery	919	250	75	97.500
23	Cimitero Comunale C	Cemetery	632	172	52	63.984

Table 3.1 – Plants of the Montevarchi REC project – Tender document: Project of technical and economic feasibility and service and management

From the installed power and the consumption profile of residential and commercial users, it is possible to calculate that the REC will be able to cover 23.41% of consumption, for a total of 2,216 homes or, alternatively, 27% of 31,800 m2 of offices. In the case of Montevarchi, a community has been estimated that will achieve a 27% reduction in consumption for 320 families and 26,560 m2 of offices, which are estimated to consume five times more than residential ones.

Among the stated objectives of the initiative are the production of energy, environmental and socio-economic benefits for the community, among these there are:

1) Improvement of the environmental situation, reducible in avoided annual emissions equivalent to the 259 TOE (or the equivalent of this amount in tons of oil)
2) Low O&M costs
3) No acoustic pollution

4) Possibility to involve the local installers and maintainers

From the time schedule, it is previewed that from the start of the works to the final testing won't pass more than eighty days. From the proposal, it is previewed also all the activities of ordinary and extraordinary maintenance of the facilities, composed of PV modules, ESSs and recharging regulators, inverters, the electrical system that is in charge to distribute the electricity, and support structures. All the components of the facility have to be maintained operational and efficiently by the operator, and with the proper supervision, activity has to maintain an adequate standard level of service.

Management service and constitution of the REC

The concessionaire proposal is mainly divided into two parts. The first one is the constitution and the starting of the REC, involving all those activities of assistance for the operations concerning the constitution of the REC like the involvement of the local population and the investment for the construction of the first plant, both remunerated with the feed-in tariff generated from the plant. The second one is the management of the CER as all the monitoring and reporting of the users consume through a management platform. This last remunerated retains a percentage of the REC revenues.

Green Wolf has been in charge to draw up a proposal of Statute and a Regulation for the REC, which will identify in the proposer the subject delegated to the management of the energy community that will be founded by the Grantor as a founding member.

The stages of a REC are the Constitution and the start-up activities, the management and the development that can be translated into an extension of the catchment area. The following is reported in detail what comprehends each phase.

- REC constitution

  The first step of this phase is the research and localization of an area, public or private, suitable for installing a photovoltaic system. Then the system is modelled, adapting it to nearby users who want to participate in the community. In this phase, the concessionaire will ask the administration for the right to build the plant on the surface previously identified. The Concessionaire will bear all the costs relating to the realization of the feasibility studies involving the technical/energy, social, economic, environmental and regulatory fields.

  Following the preliminary analyses, the concessionaire proceeds with the actual constitution of the legal entity, accompanying the Administration in drafting the statute and regulation of the Energy Community, as well as managing the constitutive process with the competent bodies. The timing of the steps envisaged for the establishment of the REC is shown in the

Figure below, from the expression of interest to the Administration to the start of the works. The whole process is estimated to last a maximum of 6 months. As already mentioned, the legal constitution of the REC takes place after the awarding of the Concessionaire.

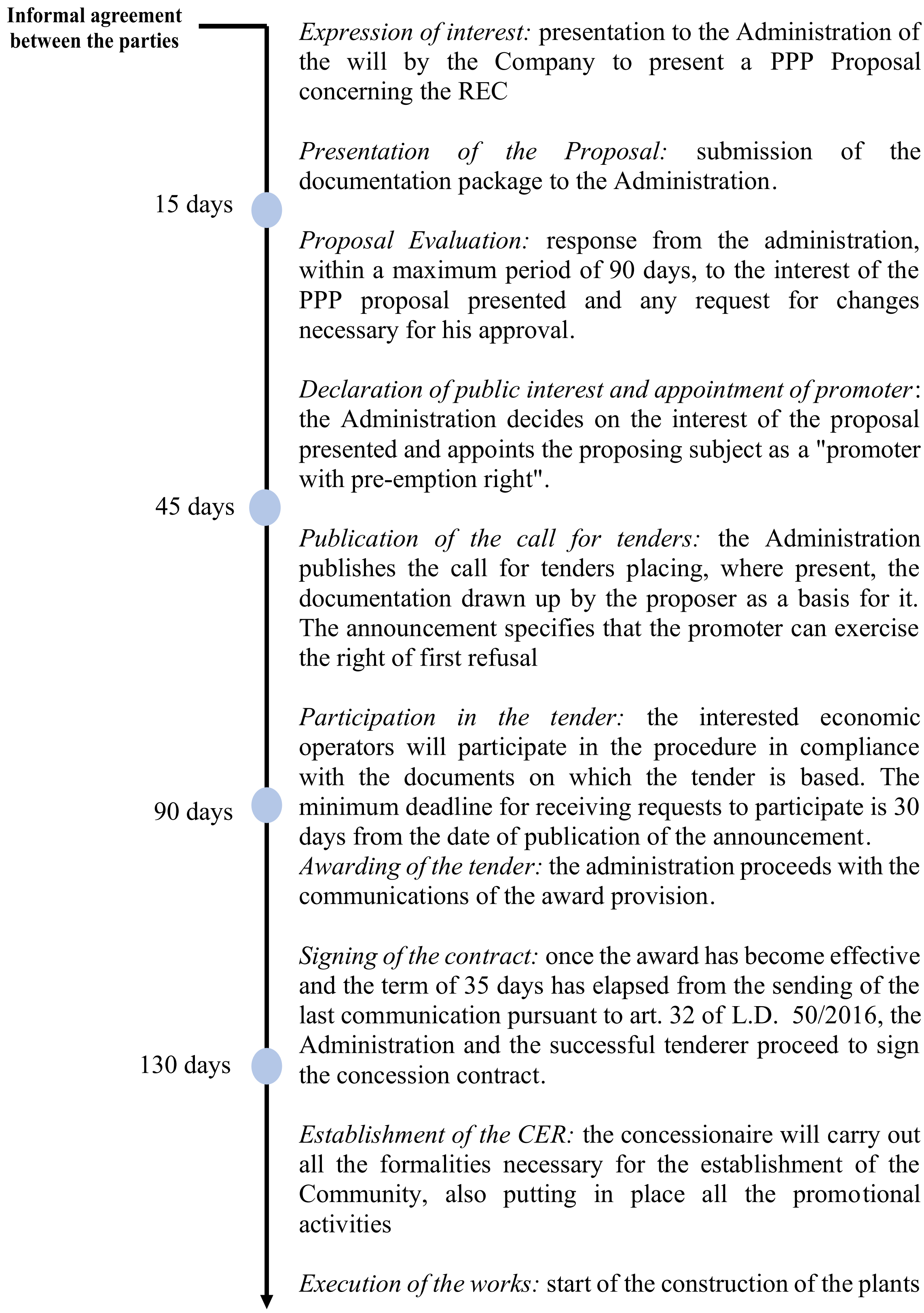


Figure 3.1 – REC constitution timeline – Tender document: Project of technical and economic feasibility and service and management

- REC management

  As regards the management of the REC, the Concessionaire will use a special management platform, which allows for the monitoring and recording of all the energy and economic parameters of the utilities. It is an online platform that will integrate community monitoring, reporting, energy and economic management. This result is also functional for the production of statistical results useful for assessing the community's operations and planning future expansions. The name of the platform is "@ndromeda©" and it will also integrate all of the REC's flow management activities by interfacing directly with users. In fact, each member has the right to access their personal energy portfolio where it is possible to view their credits achieved through the energy produced by their own photovoltaic system and/or by the virtuous behavior that has led to energy savings for the community or to maximizing energy sharing. energy within REC members. Furthermore, in the near future, the platform will provide users with notifications to better optimize energy flows, and as regards user assistance services, it will have some sections such as FAQs, suggestions to make users aware of energy-saving habits, a list of useful contacts and the calendar of scheduled maintenance. All these activities from the management of the energy flow and the possible installation of the storage system will constitute the Smart Grid infrastructure, as already defined in chapter 2.

- Development of the Community

  One of the prerogatives of REC di Montevarchi is the possibility of expanding over time. As mentioned before, the role of the platform and its reports is fundamental for this purpose. Based on these, in fact, it is possible to expand the perimeter of users and identify which are the most suitable to join and where to place the new energy plants. This is not an activity to be carried out once, but on an ongoing basis with a view to constant research and expansion. During the expansion phase, the possibility is envisaged for potential users to participate in the investment for new plants, in exchange for a remuneration designed by the community in proportion to their contribution. However, the systems become the property of the community, and their management is in the hands of the Concessionaire. This solution represents an optimal alternative for maximizing RES revenues as the transposition of RED II has attributed an incentive system only to collective self-consumption, eliminating on-the-spot metering.

  The Concessionaire also has the right to activate an awareness campaign to involve the local population and which is essential for the success of the project, in accordance with the literature. The tools that will be used are information posters, multimedia totems, apps, digital platforms and wallets to accumulate tokens thanks to virtuous behaviour.

- Economic model

  The activities that the concessionaire must carry out are mainly that of investment and subsequent management of the community, which are remunerated differently. The former is remunerated through the sale of the energy produced, as well as an incentive tariff generated by the plant, while the latter is remunerated by withholding a part of the total revenues generated by the REC. The incentive tariff will be divided between consumers and producers in a different way according to the type of who has borne the costs for the installation of the system that generated the incentive quota.

  If the investment is totally borne by the Concessionaire or a private individual, the majority of the tariff will be dedicated to them, to cover the costs of the investment. A small portion of the incentive will go to consumers. In the event of an investment supported entirely by the Administration, the entire share of the incentive rate will be available to the Administration which will be able to independently decide whether to keep a part for itself or whether to dedicate the entire amount to the savings of consumer citizens. In the case of mixed investments between the Administration and Concessionaire, the percentages of distribution of the incentive rate will be agreed upon from time to time, to ensure adequate savings for citizens while allowing the Concessionaire to recover the investment made. In the case of a plant built through crowdfunding of CER members, the entire incentive rate will be divided among the investors, proportionally to the commitment undertaken, while only a small part will be allocated to the savings of the other consumer members who have not contributed to the plant. In this sense, therefore, the distribution of profits among users can be considered to be carried out in a meritocratic manner, an element which, as seen in the literature, represents a very important element in the proper functioning of a REC and in its subsequent developments.

  The concessionaire provides a breakdown of the shares received from the GSE according to some percentage terms:

  1) Savings from self-consumption: 85% of the savings obtained by the Grantor thanks to the physical self-consumption of its buildings will be allocated to the return on the investment, the remainder will be available to the Administration that can share it with the consumers, finance other plants or share it with the energy poorer citizens.

2) Sale of energy through the dedicated collection: 85% of the portion obtained for the sale of energy will be retained by the Concessionaire, reduced by the percentage for the management service. The remainder will be available to CER consumers.
3) Restitution of the tariff components: the amount collected by the CER thanks to the refund of part of the tariffs linked to the transport and distribution of energy, will be entirely available to consumers, reduced by the percentage for the management service.
4) Incentive tariff on shared energy: the portion collected by the CER and linked to the incentive tariff will be distributed, reduced by the percentage for the management service, 85% will be reserved for the Concessionaire to cover the investment costs of the plant; the remaining portion of the incentive will be available to the CER and can be shared among consumers.
5) The plant manager will be entitled to 10% of the flows transacted by the CER, reduced by the other items.

3.1.2 Agreements

This section illustrates how the relationships between the various interested parties are regulated from a legal point of view. This part is extremely important as, from the documentation and the interview with Ing. Longo of the Municipality of Montevarchi (2022), it was possible to deduce the single legal-administrative model developed ad-hoc for this initiative. This was created in synergy with the GSE and promoted by the Union of Italian Provinces, as it could represent a potential tool to encourage the implementation of the REC under the PPP regime in the various Italian provinces once the legitimacy has been received from the Regulatory Authority ARERA (S. C. Martini, Longo A. 2022).
Below, in Figure 3.1.1, there is a diagram of the organization of the REC which indicates the nature of the relationships existing between private and public entities.

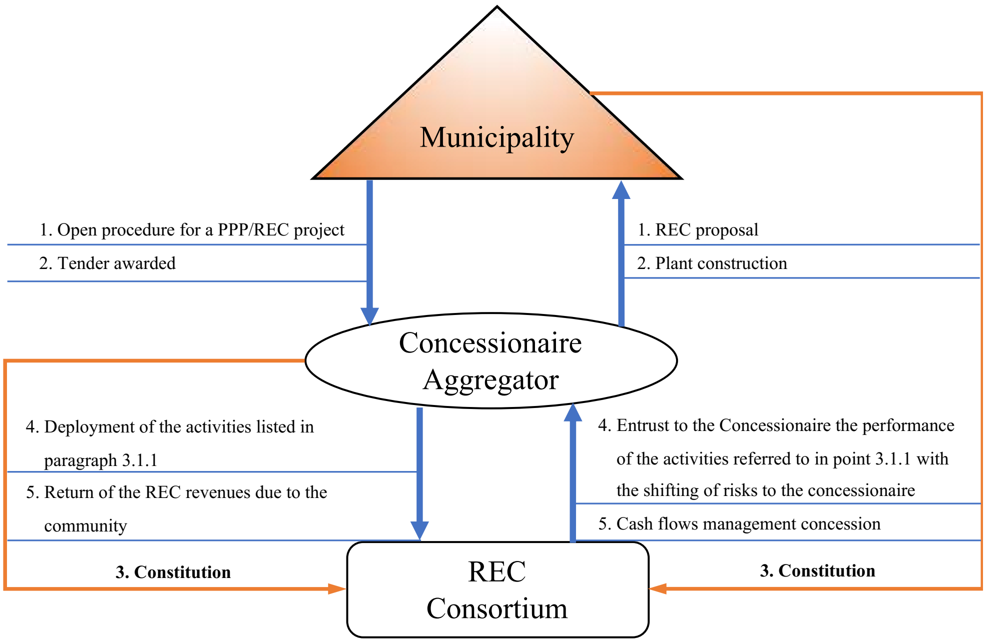


Figure 3.2 – Administrative and legal model of the Montevarchi REC – personal elaboration of the information taken from Tender Agreements

The REC of Montevarchi will assume the legal form of a consortium company having, among other things, the corporate purpose of setting up a non-profit REC. Relevant information from the REC Bylaws and Service Agreement is as follows.

- The object of the PPP is not the immediate establishment of the Consortium but mainly the construction of photovoltaic systems. The juridical constitution is something that happens after the assignment by the grantor (S. C. Martini, Longo A. 2022).
- The producer members will have to supply the owned or available renewable energy plant connected to the distribution network underlying the same primary transformation substation.
- The members of the REC are divided into Finance Members and Ordinary Members. The former are the Municipal Administration and the Concessionaire, while the latter are the consumers and producers.
- The share capital is ten thousand euros which will be fully paid up by the Founding Members.
- Producer members will be given additional voting power
- The mandate of the Chairman of the BoD is paid
- The Consortium will entrust the Concessionaire with the activities referred to in paragraph 3.1.1. including treasury services. The two entities will have to maintain ongoing relationships with each other.

- The Concessionaire will keep all the economic benefits generated by the REC activity and in the event of participation in the financing of one or more plants by the grantor, the economic benefit will be appropriately distributed following its investment contribution.
- The 10% of the economic advantage achieved by the REC will be retained by the Concessionaire as a risk premium.

3.1.3 Economic and Financial Plan

The economic-financial planning relies on the assumptions listed in the other tender documents and reported in the previous paragraphs in compliance with the constraints set out in Article 3.1 of the Public Contracts Code, such as the economic and financial balance of the concession, the financial sustainability, and conditions of economic convenience. The latter is usually expressed in the IRR and in the NPV, while financial viability is measured by the DSCR (Debt Service Cover Ratio). Economic and financial equilibrium is achieved when the project's revenues cover operating costs, investment costs, the cost of invested capital (debt and equity, the latter aimed at remunerating the systemic risk assumed by the holders of equity investments in the company project) and tax charges. In other words, equilibrium occurs when the NPV is close to zero, the IRR is around the weighted average cost of capital (WACC) and the IRR for the shareholder is around the expected return/cost of own capital (Ke - Cost of own capital). Therefore, in the event that the shareholder's NPV or IRR is higher than the expected return, it allows the Concessionaire to be protected from potential economic losses deriving from project risk, mitigating or even cancelling the operational risk.

In the first 12 months of the Concession's duration, the Concessionaire carries out energy requalification interventions in the form of installation of photovoltaic systems, the total value of which is estimated at approximately Euro 2,031,695 excluding VAT, in addition to revamping interventions, equal to Euro 109,890, corresponding to the tenth year of the Concession. The total amount of the investments envisaged during the period of validity of the Concession is therefore € 2,346,930, including technical costs.

During the construction phase, which is estimated to last 12 months, it will be financed entirely by the Concessionaire through a 20-year loan, like the one for the entire duration of the Concession. The condition of the loans is a commitment fee of 2%, an interest rate of 3%, a substitute tax of 0.25% and an upfront fee of 1%.

Concession revenues at the end of the period are calculated at €6,165,878 with total annual management costs of €1,379,292.

For the purposes of this dissertation, it is not useful to deeply analyze how the Economic and Financial plan was built, hence it is chosen to give some key information concerning this fundamental document in the Table below.

Indicator	**Value**
Project IRR	6,04%
NPV	12.380 €
DSCR	1,65
LLCR	1,38
WACC	5,98%
Payback period	11,9 (years)
Financial Structure objective of the Concessionaire	50%
Value for Money	187.075 €

Table 3.2 – Economic indicators – taken from Relazione illustrativa al PEF

According to the results of the model, it is possible to affirm that the project is sustainable in the long run since the IRR is greater than the WACC and the NPV pre-finance is greater than zero. It is important to specify that the cash flows for the shareholders are not reported since there isn't preview of the distribution of income flows to the shareholders during the Concession to give more guarantees concerning the financing equilibrium of the concession. Concerning the bankability of the concession, all the indicators such as the DSCR that indicate the is the ratio between the operating cash flow achieved during the year and the annual requirement for the service of financial debts (repayment of principal + interest) and the LLCR (Loan Life Cover Ratio) that is the ratio of the present value of operating cash flows to the present value of the needs for servicing financial debts, are always greater than one for all the duration of the Concession, reaching the minimum at 1.56 for the DSCR and 1.059 for the LLCR. The payback period is 11.9 years, far from the expiry of the concession.

To compute the value for money the proponent has implemented the Public Sector Comparator (PSC) methodology. Using statistical and econometrical tools, this methodology aims to quantify in euros, the risks that the Concessionaire with the PPP solution bear and the others that instead are retained by the Public entity. In particular, the VFM formula is:

VFM (PSC) = PSC base + competitive neutrality + transferrable risk + retention risk

In which the PSC base includes the cost of capital and the operative costs, both direct and indirect, the competitive neutrality consists in the remotion of every competitive advantage that the administration could receive in case the infrastructure would be built with traditional public procurement. This methodology is often use by Public Administrations to evaluate if the PPP is an optimal choice with reference to the alternative of public procurement.
Following the procedure steps, the following risks that involve the project are identified also in accordance with the Art. 3.1 of the Code of Public Contract, that are:

- *Construction risk,* which contains the design, execution, inflation, erroneous valuation, contractual breach, and inadequate technology risk.
- *Demand risk,* which contains the normal market demand contraction risk and the contraction of the specific demand contraction risk.
- *Availability risk,* which contains the extraordinary maintenance risk, the performance risk and the availability of the facility risk.

Through a Montecarlo simulation, were computed the numerical values of the risks transferred to the Concessionaire, in particular, the results are reported below:

Computations of the VFM of the Concession	
Construction risk transferred to the Concessionaire	130.372 €
Operative risk transferred to the Concessionaire	38.562 €
Maintenance risk transferred to the Concessionaire	30.522 €
Total risks transferred to the Concessionaire	199.456 €
Project NPV	12.380 €
VFM of the Concession	-187.075 €

Table 3.3 Estimates of transferred risk to the private – Data taken from Relazione illustrativa al PSC

In the computation, the competitive neutrality and the retained risk are assumed to be zero. Seeing the results, it is possible to affirm that for the grantor is not less than 187.075, in other words, the risks that are transferred to the Concessionaire are higher than the project NPV.

3.2 The Multi Actor Multi Criteria Analysis in the Transition Management field

With reference to the work of Lode et al. (2021), in this paragraph, the case study of Montevarchi with the MAMCA and the linkages with the field of Transition Management will be analyzed. Contrary to what happened in the work of Lode et al., here the case is used differently, in a different country and for different purposes, all well specified as the analysis is implemented. First, an overview of what TM is and why it is useful to bring it to the fore in the case analysis will be given, then the MAMCA methodology, how it is implemented and the fields of application that have been found in the literature will be covered.

The analysis of the Montevarchi REC case will be developed and then the results will be discussed. It aims to answer the research question: is PPP an optimal solution to satisfy most of the objectives of the stakeholders involved into Montevarchi REC project? Through semi-structured interviews and questionnaires sent to the selected stakeholders, this analysis provides information on the interests of the stakeholders that are present in the Municipality, and on how they interact and can participate in a co-creation approach. As anticipated at the beginning of the chapter, the analysis focuses above all on what is in the state of the art of the initiative, which in this case corresponds to the action of a public body that has opened an Open Procedure for a PPP for a project REC. In this sense, the chosen methodology is perfectly applicable because it allows to empirically explore the motivations that led to this, and because the chosen alternative becomes optimal compared to the already available alternatives, such as traditional public procurement. It is important to specify that this methodology, according also to the paper of Lode at al. (2021) that insert it in the TM practice, is also promoted by the European project "Renaissance" which aims to provide community-centric, scalable, and repeatable solutions for the implementation of new business models and technologies to support clean production and co-distribution of energy at the local community level (Renaissance 2022).

3.2.1 Transition Management and the MAMCA methodology

In the study of Lode et al. (2021) the MAMCA was introduced to give a practical application to the field of Transition Management, judged by the authors as a managerial approach to innovation which however lacks practical tools and methods to apply sustainable practices which it promotes. According to Geels, F.W. (2002) (see Lode et al. 2021) TM analyzes the transition from three different perspectives:

1) The global called "landscapes" consists of all changes that occur very slowly. It is composed of well-established actor interactions that dictate specific rules and requirements to the other spheres, which are integrated into it.
2) The meso level is the sphere composed of all the dominant components of the entire system, such as infrastructures, policies and technological innovations.
3) The micro level is separated from the dominant system and in this space new possible solutions and practices find application and experimentation. This level has the potential to influence the meso level by generating a new equilibrium.

Hendriks (2009) for the application of TM, propose the establishment of a transition arena, which consists of the creation of a network of actors experimenting with innovations. The transition arena is found at the micro level as the actors operating in it are innovators, developers and leaders who cooperate to address existing socio-technical issues. Loorbach et al., (2015) provide a practical guide to managing the transition, of which the key points are reported:

- Establishing a transition team

  TM can be developed in a context in which the actors (individuals or organizations) face persistent problems and there is the possibility of a transaction. Hence it is clear that all the process starts with the people and their shared needs, accompanied by the will to find new solutions. The transition team is better to composed of actors with different backgrounds and experiences that however share the same values and vision to successfully undertake a transition toward sustainability as soon as possible.

- Developing sustainability visions, pathways, and a transition agenda

  The main issue concerning the TM process is the structuring and envisioning process. These started with a deep knowledge of the societal problem and the challenges by the actors, with the awareness that their actions could have a potential cumulative impact on the social system. This process reinforces the definition of the societal problem and the changing in the daily routine of the actors involved.

- The initiation and execution of transition experiments

  The execution of transition experiments with social learning objectives is another important part of the transition pathways. More important is to define proper measures to identify the proper experiment. The point is to measure how much experiments and projects contribute to overall system sustainability goals and to assess the extent to which one experiment enhances another. The aim is to create a portfolio of transition experiments that are mutually reinforcing and contribute to sustainability goals in a significant and measurable way. All sorts of actors can be involved before and after these experiments that are not regularly involved in discussions about these long-term issues. These could be, for example, small businesses, consumers, citizens, community groups, etc.

- Monitoring and evaluating the transition process

  Monitoring is the key activity in the search and learning process of transitions. Actors within the transition arena must be monitored regarding their behaviors, networking activities and networking activities. The transition agenda should be monitored for agreed actions, goals, projects, and instruments. Experiments need to be monitored in terms of specific new insights and knowledge and their transmission, but also in terms of social and institutional learning. The transition process itself should be monitored in terms of progress, barriers, and areas for improvement. Integrating monitoring and evaluation into all stages and levels of transition management can stimulate a process of social learning that arises from interaction and cooperation between the various actors involved. In each of the above clusters of activity, the building of coalitions and networks combined with systematic structuring and discussion integration is critical. The Transition Arena aims to stimulate the formation of new alliances, partnerships and networks. Most commonly coalitions form around transitional paths or experiments, or around specific sub-themes from which arenas form arenas. The basic idea of change management is to create new coalitions, partnerships, and newly formed coalitions that enable continued pressure on politics and markets to secure the long-term direction and goals of the change process.

Concerning the TM, a variety of research highlights the presence of some obstacles to his application, such as the lack of connection to the political sphere of decision-making, power relations, inequality, and social representation (id.). For this reason, it is possible to affirm that fostering the TM process, is fundamental to the political will and that transition agendas depend on the interests of those who lead the process. After having reported all these criticisms about the power relations, representation, and guidance of the transition process, there will be introduced the MAMCA as a tool to use in TM to analyze and assess the roles that the various stakeholders have in implementing a transition project making a differentiating scenarios evaluation.

With reference to what emerged from the interview with Mayor Martini C.S. (2022) and the TM guide of Loorbach et al., (2015) can be found some similarities among this last and what happened in the town of Montevarchi. Indeed, the so-called "Commissione Futura" is very similar to the definition of the Transition Team. They are similar since it composed of stakeholders, both innovators and leaders, who share problems and values and are united to find new opportunities and solutions to implement in the field of energy transition and renewable energy. In accordance with the above, the fact that at the municipal level are reunited all the major stakeholders of the territory allows for reinforcing what are the missions and the values commonly shared within the community, which in turn allows for creating a sense of participation and long-term vision of the transition. Lastly, the fact that this initiative is organized and incentivized by public entity for the community, allows overcoming the negative externalities of the political power control issue present in the literature, which represent one of the major obstacles to the Transition management practice. For the purposes of this dissertation, however, the MAMCA is developed academically ex-post the decision to undertake the PPP but the association with the TM practice can be useful for other similar future initiatives, in order to make effective, optimal and fair decisions involving also the variety of the stakeholder interests.

3.2.2 The MAMCA and case study design

Definition

Macharis et al. (2012) defined the MAMCA as a multicriteria approach used to evaluate different alternatives such as policy measures (Turcksin et al., 2011), different scenarios, new technologies or performances (Kourtit et al., 2014), with reference to the different stakeholders that are involved. The major difference with the widely used multi-Criteria Analysis is that the MAMCA includes centrally the point of view of different stakeholders, while the other present alternatives are evaluated on several criteria, that not necessarily are of stakeholder interest. From Baudry et al., (2018) the analysis can be seen as an effective tool also in decision-making issues under uncertainty and a variety of stakeholders, each one considered as important as the others, while Macharis, C. (2004) and Janic 2003 (see Macharis, C. 2010) it allows solving the issue of the Multi-Criteria Decision Analysis since it considers a variety of criteria but only with reference to one stakeholder. This kind of analysis, which can be seen an extension of Multi-Criteria Decision Analysis (MCDA) is concentrated on non-numerical and non-economical values in its evaluation (Macharis et al., 2012b) that could guide the decision makers toward their final decision involving a variety of point of view in the decision process.

Methodology and case study design

Again Macharis et al. (2012) and Macharis et al. (2009) define the necessary steps to follow to implement the MAMCA. These are listed below declining them with a focus on the REC initiatives. In this way, it will be easier to conceptualize the analysis of the Montevarchi case reported in the following paragraph.

Step 1: Defining the Problem and the alternative scenarios

As a first step, the current situation is analyzed, and other scenarios are individuated. The scenarios or the alternatives can be of different natures, such as long-term policy measures, organizational changes, or the application of new technology. To profit most from MAMCA, the problem definition or the possible solutions can be explored by the direct involvement of the stakeholders or also with alternatives present in the literature. Related to the case study of Montevarchi, the alternative scenario is considered one of the case studies, as that is the creation of the REC through the PPP, with all the features that were described in the case presentation section. The other scenarios instead are extrapolated by the current methods used to set up the RECs operative in Italy, which are findable in the last report of Legambiente made by Eroe K. et al. (2022). Hence the second scenario is the traditional public procurement, as that is the situation in which the public entity commissions the construction and the management of the structure of a third party while it bears all the risks involved and the financing and running of the facility. In this scenario also fall the cases in which the public entity is financed partially by public funds that are not coming from the public balance, such as the PNRR or Regional Funds. The third alternative is the set-up of the REC made by its potential users, which includes all the activities of organizing, commissioning, and financing the infrastructure. It is the case for instance of the first industrial REC called “Energia Verde Connessa” located in Imola (Metropolitan city of Bologna). A fourth scenarios that is also present also in the literature, is the REC provided entirely by the Esco, as the REC “Solisca” in the Municipality of Turano

Lodigiano made by the Esco Sorgenia or the "Monticello Green Hill" of the Municipality of Monticello Brianza and of the "Energia Verde Connessa" in the Municipality of Imola (Eroe K. et al. 2022). Hybrid solutions can be found in every scenario and for obvious reasons all the alternatives can't be listed in this analysis, however, the key elements of the alternatives remain constants and they will be evaluated on them, rather than focusing on the possible nuances that can take, for instance, the organizational, financing or management choices of the facility.
The scenarios of the analysis are resumed in the table below.

Scenario	**Description**
PPP	This is the situation that this study wants to assess since it represents a novelty in REC construction in Italy. This is a solution in which all the risks are transferred to the private party and all the activities are financed by the private in exchange of a limited risk premium. In this framework, the private and the public entity collaborate to the constitution of the initiative leaving the rest of the REC revenues to the users.
Public Procurement	Here traditional public procurement is used for the construction of the facility and the other activities necessary to start the initiative. This leaves to the public entity all the risks and possible drawbacks that are reported in the first chapter. In this scenario, the Municipality has an active role in participating and administrating the REC, and for this reason, it is supposed to have more control over the infrastructure and the revenues that it could generate since it assumes the role of guarantor between the users and who contribute to building and managing the infrastructure.
Users' initiative	This is the "bottom-up approach" that was founded in the literature and in some cases of Italian communities. The basic component here is the users' values sharing and the will to aggregate to be energetically independent. This solution has the fundamental aggregation component but has the need for external competences that must be managed and coordinated. The risks are shared between the community members.
ESCo	This is an alternative that is already present in Italy and compliant with the national legislation on REC. In this scenario, the ESCo provide the infrastructure and the needed investments. The Company in accordance with the users, sell the energy to them, and at the end of the period necessary for the recovery of the capital, the plants become propriety of the users. This scenario is inspired at the industrial REC in Imola implemented by the ESCo Bryo Spa. In this scenario the Municipality however can assume the role of promoter of the initiative.

Table 3.4 - Scenarios – Personal Elaboration

Step 2: Stakeholder identification and engagement

In this step, people and the organization that are affected by the problems of the proposed scenarios are individuated and consulted to participate in the MAMCA process. The same process can be seen in the creation of the transition arena proposed by TM, that in this case was made by the Municipality of Montevarchi and its "Commissione Futura". Several methods can be found in the literature to identify relevant stakeholders, such as the stakeholder theory and the salience analysis. However, for the case study, the snowball method has been chosen, as used in several research fields. It consists of the identification of the stakeholders in which each one mentions the others that it retains to have a stake in the project (Naderifar et al., 2017). From Banville at al. (1998) stakeholders are everyone that has an effective interest in a particular issue that can affect it, and/or can be affected by it or they affect each other.

In the case of Montevarchi, the Mayor took on the parts of the municipal institution, that he strongly wanted and took steps to arrive at the PPP proposal object of the case study. It could have also assumed the role of Vice-President of the Italian Provinces, however, following the interview it emerged that the Municipality would have represented a more relevant stakeholder for the purposes of this thesis, above all for the number of interests it has in the project which is of far greater than the other association. The other selected stakeholder is Green Wolf Srl that is one of the two proponents of the initiative. Following the snowball method, it has been contacted following the interview with the mayor and also interviewed thanks to her intermediation activity. From the interview with the representatives of Green Wolf (2022), it emerged that most of the design of the REC was done by themselves, hence in the following analysis, Green Wolf assumes the role of "aggregator" and so the private entity that is entitled to manage the community. This selection of stakeholders finally coincides with a similar analysis of projects that are present in the literature usually found in a local government entity, an ESCo and a citizen cooperative or companies.

The stakeholders that participated in the evaluation are schematized in the following table. The date that refers to the questionnaire is relative to the moment in which it has been received.

Stakeholder	Representants	Type of contact	Date of the contact
Municipality	The Mayor Dott.ssa Silvia Chiassai Martini and Ing. Longo Antonio	Interview Questionnaire	27/09/2022 16/11/2022
Aggregator (Green Wolf Srl)	Dottor Paolo Ferrero and Ing. Mattia Tucci	Interview	18/10/2022
	Pres. Stefano Bonino and Ing. Mattia Tucci	Questionnaire	29/11/2022

Table 3.5 – Stakeholders

Step 3: Criteria Definition and Weighting

This is the phase in which whoever is carrying out the study is in charge of finding the criteria or interests that the interested parties have in a particular context, which will then be evaluated by them, for example through surveys. These targets are the criteria used to evaluate the impact of scenarios on stakeholder contributions. The objectives can be identified through different ways, for example by directly asking the selected stakeholders through semi-structured interviews, from case studies in the literature or from expert suggestions. They then need to be rated by each stakeholder, for example using Direct Rating where each criterion receives points on a 0-100 scale (Lode et al., 2022) or pairwise comparison, such as the Analytical Hierarchy Process (AHP) of Saaty (see Lode et al., 2021). Then based on the points received, each goal receives a weight in reference to the points that the other goals have received. The weighing process can be done manually by the developer of the analysis and not necessarily with AHP or Pairwise comparison methodologies. For the Montevarchi case it was decided to construct a questionnaire which was administered after the semi-structured interviews. Each stakeholder was asked to respond to a questionnaire with the pre-set objectives found in the literature, the interviews carried out and the personal processing of information from secondary sources and considering the specificity of the national framework in which the initiative is located. The latter are considered validated by the stakeholder once they have received a point greater than zero, which then happened for all of them. The methodology chosen is the Direct Rating with a scale from 0 to 100 points. The scores were finally normalized and scored against the most important ones. Using Huang H. et al. (2020) it is possible to explain in detail the normalization process. Suppose that there is a set of criteria in one stakeholder group, called $C = \{f_1, f_2, ..., fm\}$ and the priority scores are $W = \{W_1, W_2, ..., Wm\}$, then the normalized weights are indicated as $w = \{w_1, w_2, w_m\}$. The final weight criterion k will be:

$$w_k = \frac{W_k}{\sum_{j=1}^{m} W_j}$$

And the sum of all the normalized scores for each stakeholder must be equal to one.

$$\sum_{j=1}^{m} W_k = 1$$

Taking inspiration from the final decision tree of Turcksin et al. (2011), as follows is reported a similar scheme of stakeholders and their interests relative to the case of Montevarchi, each one accompanied by the relative source by which they are retrieved. It is important to specify that in the questionnaire instruction it has been given the possibility to the respondent to insert additional elements, however, nobody has exploited this possibility. In Figure 3.3 there is presented the criteria tree, as elaborated in Macharis et al. (2012), complete with the specifications of the sources from which the criteria were recovered.

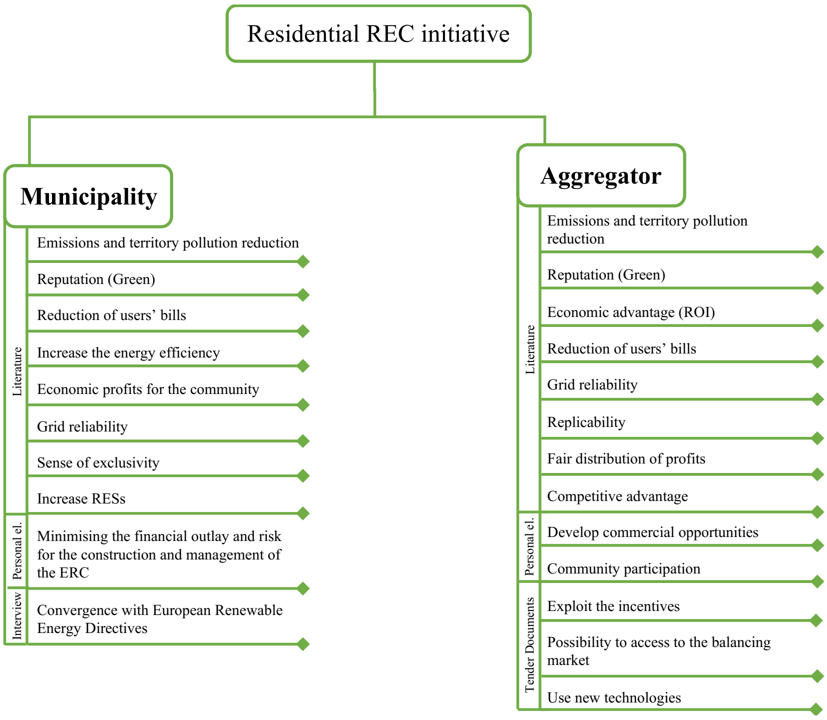


Figure 3.3 – Criteria of the Stakeholders in relation to the creation of the residential REC

The table below instead reported the scores given to each criterion and the relative chart showing the normalized weights assigned to each one. There isn't so much difference in weights since every criterion is reputed important, except for the interest in exploiting the incentives for the aggregator.

Stakeholder	Criteria	Points	Stakeholder	Criteria	Points
Municipal Body	Emissions and territory pollution reduction	80	**Aggregator**	Emissions and territory pollution reduction	100
	Reputation (Green)	100		Reputation (Green)	100
	Reduction of users bills	100		Economic advantage (ROI)	80
	Increase the energy efficiency	80		Reduction of users bills	80
	Economic profits for the community	90		Replicability	100
	Grid reliability	80		Fair distribution of profits	100
	Sense of exclusivity with the initiative	100		Competitive advantage	100
	Increase RESs	100		Develop commercial opportunities	100
	Minimising the financial outlay and risk for the construction and management of the ERC	90		Community partecipation	100
	Convergence with European Renewable Energy Directives	100		Exploit the incentives	50
				Possibility to access to the balancing market	90
				Use new technologies	90

Table 3.6 – Direct Rating of the Stakeholders criteria – Submitted questionnaires

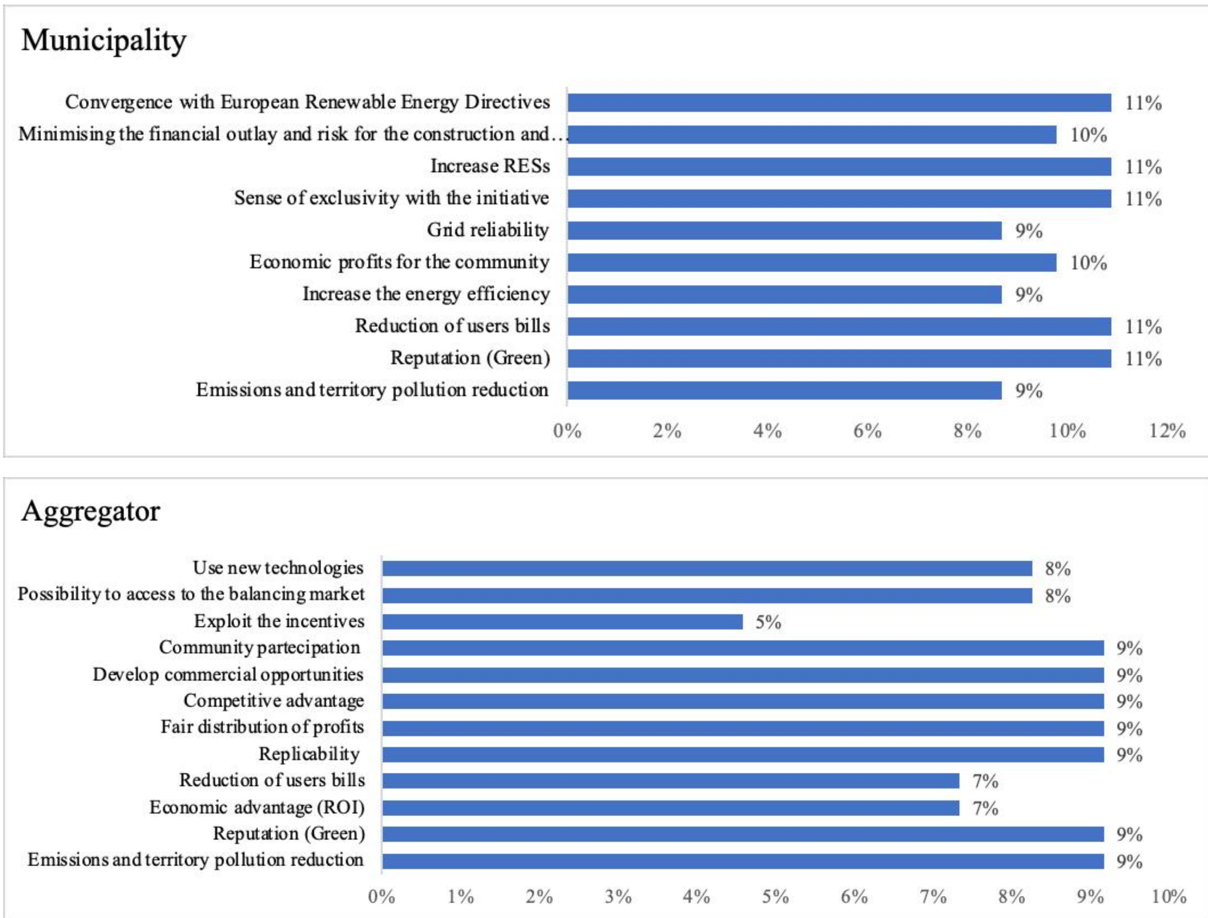


Figure 3.4 – Normalized weights assigned to the stakeholders' criteria – Personal elaboration

Step 4: Scenarios/Alternatives Measurement and Measurement Methods

Once the objectives have been weighted according to their importance to each stakeholder, the scenarios are evaluated for their performance in meeting the objectives of the various stakeholders. In this phase, each scenario (phase 1) is evaluated in the degree of fulfillment of the various criteria, using the indicators and the appropriate measurement method (phase 4), this, for each stakeholder (phase 2). It is important to point out that the scenarios formulated in step 1 represent a broader concept than the simple "alternative" as the first also includes the environment in which the alternative operates, useful for giving the analysis a more precise meaning (Macharis et al., 2012a), especially in cases where there are multiple political actors and influences. This evaluation can be done directly by the stakeholders (Huang H. et al., 2020; Lode et al. 2021; Schär and Geldermann, 2021), by the analyst conducting the research, (Macharis et al., 2012a) or through expert opinions (Lode et al., 2022). The first alternative was that the analyst must acquire multidisciplinary knowledge to evaluate the criteria. The assessment made by the stakeholders cannot be considered the best choice in cases where they have an interest in a certain alternative being chosen. In this case the alternative produces distorted results (Macharis et al., 2012a).
The given performance score is a numerical indicator of the performance of an alternative in terms of a single criterion (Schär and Geldermann, 2021). This is a crucial step in understanding to what extent scenarios would help meet stakeholder objectives.
Different methods are available for the evaluation such as the AHP and the Simple Multiattribute Rating Technique (SMART), which provided that the preferences of the alternatives would be evaluated on a 10-point scale while if you choose AHP, then the measurements are conducted through the pairwise comparison (H. Huang et al., 2020). For this analysis, it was decided not to proceed with the AHP and to opt for the SMART, since it will achieve the same objective but will involve a less complex questionnaire and will speed up the evaluation process compared to the other method.

To make the evaluation of a scenario based on a criterion, in Montevarchi's case, the analyst's evaluation was chosen since the second alternative is impracticable and the third would produce distorted results since one of the stakeholders (Green Wolf) plausibly has a direct interest in attributing the PPP scenario scores higher as it reflects its business model. Performance evaluation will in any case be carried out by motivating the choice made with adequate arguments based on assumptions deriving from the study of the literature on the subject and justified by adequate logical deductions based on conditions defined ex ante.

In Tables 3.6 and 3.8 are reported the evaluations of the criteria respectively for the Municipality and the Aggregator.

Municipality criteria	Public Procurement	PPP	ESCo	Users' initiative	Motivation
Emissions and territory pollution reduction	7	9	9	8	• Municipalities are more and more budget constrained that reduces the possibility to implement large-scale projects • Investment constraints can be found also within private users
Reputation (Green)	9	9	9	7	• In every scenario, the green reputation of the initiative would be recognized by the Municipality, except whenever it is made only by the Users • It is assumed that also in the ESCo scenario the Municipality will benefit from the reputation since can be also the promoter of the initiative
Reduction of users bills	7	8	8	7	• The budgetary constraint limits the extension of the project and the exploitation of economies of scale
Increase the energy efficiency	8	10	10	8	• Energy efficiency operations are evaluated for all the scenarios more than sufficient but the ESCo and PPP alternatives is objectively more inclined to provide EE interventions since they are active in this field in Italy for roughly by 20 years also with EPC contracts.
Economic profits for the community	7	8	6	9	• In a User's managed REC is more likely to have a fair profit redistribution • The contrary happens in the ESCo case thanks to its major contractual power • The PPP case is a compromise since there are some legal constraints to the profit that the private entity can reach
Grid reliability	8	9	9	8	• The REC impact is reached when it is of a large-scale dimension
Sense of exclusivity with the initiative	7	10	8	6	• The PPP allow to realize a large-scale REC without risk and investment by the municipality or the users • The fact that the Users realize an operation without any public help make the Municipality role untouched
Increase RESs	6	10	9	7	• Budget constraint alternative undermine the investment in RESs
Minimising the financial outlay and risk for the construction and management of the REC	3	9	8	10	• The expenditure for the municipality is maximized when it is made with its funds and minimum when it is made by private users • The PPP alternative is considered fairer for the Municipality for the contractual legal guarantees typical of the PPP
Convergence with European Renewable Energy Directives	8	9	9	8	• All the alternatives go toward the European Directives • The ESCo and the PPP are considered slighlty more effective following the assumption that allows more to implement large scale infrastructures

Table 3.6 – Municipality criteria evaluation

Starting from the Municipality, it has been chosen to assign generally lower points to the Public Procurement and Users' initiative scenarios relative to the other options. This is especially due since the ESCo and the PPP alternatives are the ones that make it easier to finance the initiative, and so the project that would be developed will be with a large probability bigger in size and so more inclined to develop more impactful environmental and economic results. This is also verifiable by the pilot REC initiatives that are present in Italy, that if originated by a public entity are all under the MW of power, while the ones created by users are for instance public small Mountain communities' initiatives limited to a small territory and anyway born before the REDII transposition. Except for these important limits for the two scenarios, on the other hand, they present the advantage of administrating and so retaining all the profits of the REC, limiting the technical and financial partner moral hazard behaviours. This is because of the direct control of the profits and major transparency of the accounts that if administrated only by an ESCo can be strategically maintained low, for instance increasing the operative costs, and so they cannot be shared with the REC members. PPP in this sense can allow maintaining a more transparent administration of the revenue thanks mostly to the guarantor role undertaken by the public entity, as in the case of Montevarchi.

About the aggregator criteria, in this case, it must do some little specifications since in the Montevarchi case the aggregator, Green Wolf Srl, is also the company who finances, co-fund and then manage the REC. In the proposed scenario, however, it is supposed that the REC creation will be made in different modalities, in which the aggregator can assume a role that differs from the ones of the base case scenario, in this case, the PPP. Hence it is assumed that:

- In the PP scenario, the aggregator assumes the task of management of the power flows of the community, as defined by Fioriti et al. (2021)
- In the users' initiative scenario, the aggregator does also the installation of the DERs without the financing and users' engagement activity. In some sense, it assumes the complete role of a technical partner
- In the ESCo and PPP scenarios, it assumes all the roles of financing, creation, and management of the community. The elements that distinguish one from the other concern the legal discipline of the contracts.

It follows the table of the evaluations completed of the motivations at the base of the score attribution.

Aggregator criteria	**Public Procurement**	**PPP**	**ESCo**	**Users' initiative**	**Motivation**
Emissions and territory pollution reduction	7	9	9	9	• Since in the PP case, it has been assumed that the aggregator has only a power flow management role, the scenario contributes only indirectly to the criteria
Reputation (Green)	7	9	9	8	• The reputational benefit for the aggregator is limited thanks to its limited apport to the project
Economic advantage (ROI)	5	8	9	8	• The profitability in terms of ROI is proportional to the number of activities done for the REC • The profitability in the case of PPP is slightly less than ESCo for the intermediation role of the municipality

Reduction of users bills	7	8	8	8	• Also with PP the aggregator can reach reduction of user bills if is able to involve the correct amount of users
Replicability	7	9	9	7	• There isn't so much interest in replicability in a closed user and PP initiative since the aggregator has not a particularly innovative role
Fair distribution of profits	6	8	7	6	• In cases in which the treasury role is not in the hand of the aggregator, this interest cannot be satisfied by the same • ESCo are by definition profit-oriented and moral hazard behaviours are more likely to happen compared to the PPP case
Competitive advantage	7	9	9	7	• The competitive advantage is reached through the REC initiative in its totality, hence in the case of PPP and ESCo • In the PP and Users' case is reached, for instance, if the aggregator owns an innovative power flow management technological tool
Develop commercial opportunities	7	9	8	7	• Commercial opportunities should come also from PP and Users' initiatives since in any case there is a need to get in touch with actors of the territory of reference
Community partecipation	7	8	8	10	• Users' participation is reached in a bottom-up initiative by definition • In the other scenarios is not so obvious and some sensibilization activity must be developed among the population by the aggregator
Exploit the incentives	6	9	9	6	• The incentives can be exploited directly by those who make the investment
Possibility to access to the balancing market	7	7	7	7	• The access to the balancing market is reachable only if the REC or a group of REC are large enough, for this reason it is possible only if there are aggregators that are involved in large scale projects
Use new technologies	9	9	9	9	• Technologies and IoT solution are at the base of the SG and so of the RECs

Table 3.7 – Aggregator criteria evaluation

Here basically the scores follow mainly the importance and the number of the activity that the aggregator is called to do in each scenario, following the previously listed assumptions. In fact, also in the literature, the aggregator can assume a variety of roles, and it is not obvious that all the tasks are at the end of the same.

Once that the performances are properly given and justified, it is possible to pass to the overall valuation of the final performances of the scenarios are necessary to introduce some other simple computations. Suppose that experts evaluate a series of scenarios named $S = \{s_1, s_2, \dots s_n\}$. Then, the performance score P_i of the scenario s_i is computed as reported by the formula below:

$$P_i = \frac{\sum_{j=1}^{m} p_{ij} w_j}{10}$$

The p_{ij} is the performance score of the scenario s_i on the criterion f_j, while the w_j is the weight of the criterion f_j. The score then is divided by ten to maintain the score ranges from zero to one (id.).

Step 5: Overall analysis and ranking

Every scenario is evaluated by his performance in satisfying each stakeholder's criterion. Results are then shown for each stakeholder. To show the results is then possible to visualize the outcomes with the so-called "multi-actor view", which groups all the results in a single chart and gives a holistic view of how the stakeholders interact in the proposed scenarios (Lode et al., 2021). As proposed by the same authors, MAMCA can be assimilated into TM practice, providing useful hints into how an innovation path can be managed by asking and considering all the stakeholders involved in a holistic and comprehensive way. This integration will be treated in the conclusions paragraph, finding differences and similarities with respect to the case study of Montevarchi.
Table 3.8 displays the results of the analysis, as the impact of different scenarios on all the criteria, with all the final scores.

Municipality	**Public Procurement**	**PPP**	**ESCo**	**Users' initiative**
Emissions and territory pollution reduction	0,609	0,783	0,783	0,696
Reputation (Green)	0,761	0,978	0,978	0,761
Reduction of users bills	0,761	0,870	0,870	0,761
Increase the energy efficiency	0,696	0,870	0,870	0,696
Economic profits for the community	0,685	0,783	0,587	0,880
Grid reliability	0,696	0,783	0,783	0,696
Sense of exclusivity with the initiative	0,761	1,087	0,870	0,652
Increase RESs	0,652	1,087	0,978	0,761
Minimising the financial outlay and risk for the construction and management of the REC	0,293	0,880	0,783	0,978
Convergence with European Renewable Energy Directives	0,870	0,978	0,978	0,870
Score	0,678	0,910	0,848	0,775

Aggregator				
Emissions and territory pollution reduction	0,642	0,826	0,826	0,826
Reputation (Green)	0,642	0,826	0,826	0,734
Economic advantage (ROI)	0,367	0,587	0,661	0,587
Reduction of users bills	0,514	0,587	0,587	0,587
Replicability	0,642	0,826	0,826	0,642

Fair distribution of profits	0,550	0,734	0,642	0,550
Competitive advantage	0,642	0,826	0,826	0,642
Develop commercial opportunities	0,642	0,826	0,734	0,642
Community partecipation	0,642	0,734	0,734	0,917
Exploit the incentives	0,275	0,413	0,413	0,275
Possibility to access to the balancing market	0,578	0,578	0,578	0,578
Use new technologies	0,743	0,743	0,743	0,743
Score	0,688	0,850	0,839	0,772

Table 3.8 – Final scores

From the analysis results visible in Table 3.8 is possible to affirm that for the Municipality and for the aggregator the best scenario usable to create a REC in Montevarchi Municipality is confirmed the PPP, the second best is the ESCo, since it is assumed that the business model would be quite similar, the third choice is the Users' initiative, pushed mainly by the organizational benefits deriving from the fact that people don't require sensibilization campaigns and the revenues of the REC are under the direct control of the same users. Finally, the less efficient alternative is Public Procurement, mainly because of the variety of tasks involved in REC creation and the so high complexity to manage, which can be faced in a better way if delegated to expert private agents.

3.2.3 Results

To better comprehend the analysis results as follows in Figure 3.5 are reported the multi-actor view shows graphically in aggregate the outputs. Then are visualized also the sensitivity analysis to assess the roles of the various scenarios in satisfying each criterion.

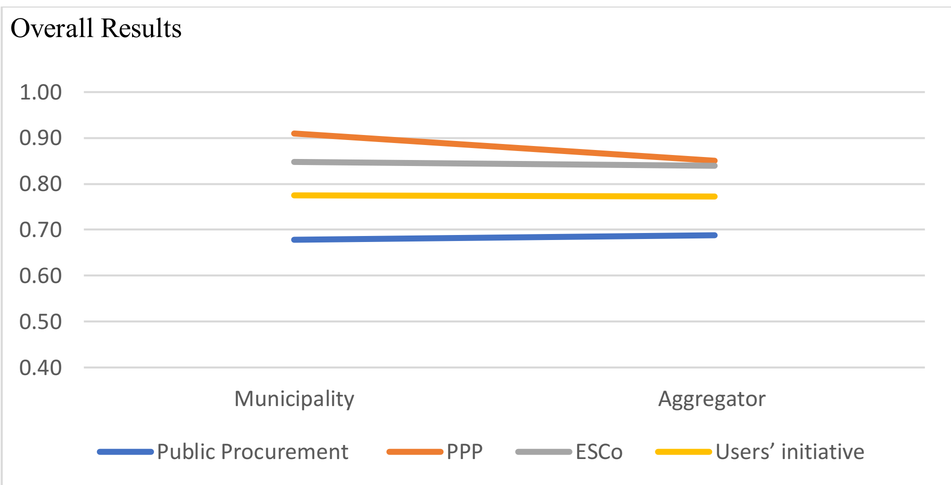


Figure 2 – Multi-Actor view of the results

It is interesting to note that, for the Municipality, direct involvement in the initiative is not optimal considering its interests since after the PPP the second solution is the ESCo scenario, in which the Municipality cannot necessarily be involved, as in the case of "Monticello Green Hill" REC in Brianza (Eroe K. et al. 2022). Clearly, in the Italian context, there are also cases of residential communities developed by ESCos where the promoter was the Municipality, such as the "Renewable and Solidarity Energy Community of Messina", promoted by the Municipality of Messina with Enel X as technical partner. The results relating to the PP show that it represents the worst alternative for the Public Administration, and to a lesser extent for the aggregator, because it can still participate in the initiative albeit with a less impactful role.
However, to better evaluate how it was possible to reach these conclusions, it is necessary to analyze how the interactions of the various interests and weights translated into an overall assessment. From this point of view, it is also necessary to evaluate which interests have contributed to the success of the PPP and those which would be better satisfied with other scenarios. Indeed, the optimality of the PPP, as can be seen from Figures 3.6 and 3.7 which show the sensitivity analysis that represents the various outcomes for each stakeholder, was not unanimously reached.

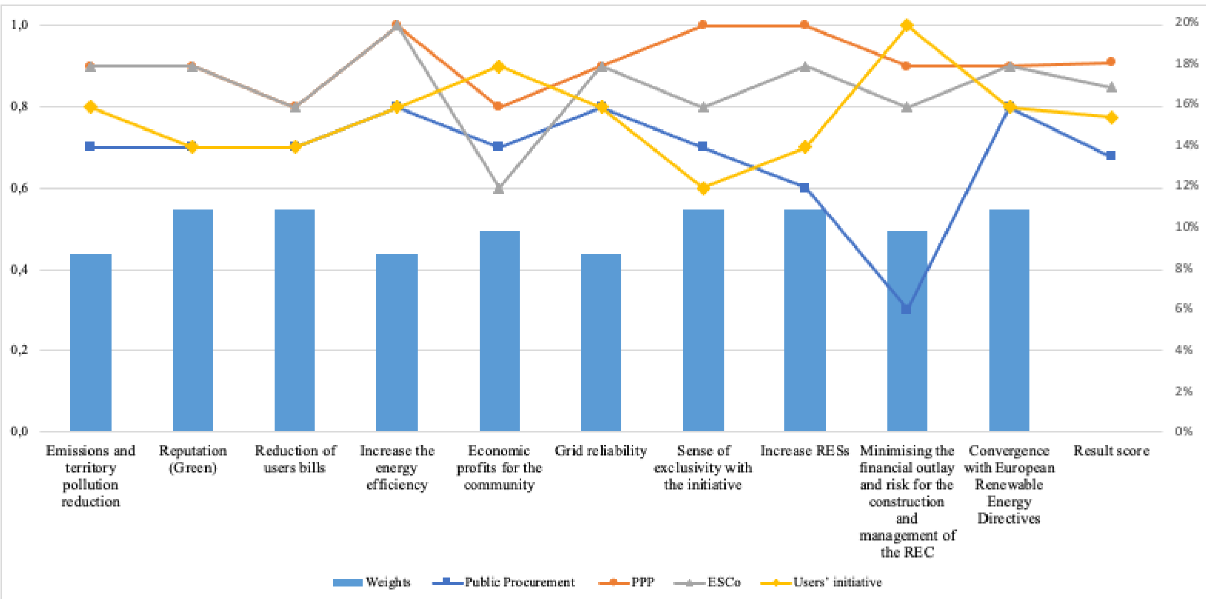


Figure 3.6 – Municipality sensitivity analysis

From the Municipality's perspective, it is interesting to observe that, confirming however the results concerning the PPP, there are however some exceptions concerning the optimality in the other interests. For instance, in the domain of minimizing the financial outlay and risk for the construction and management of the REC. In this case in fact the user initiative performs better, both with the economic profits for the community because, by definition, the user initiative scenario previews that the risks do not weigh on the Municipality since the plants will be financed and run under their responsibility, with the advantage that could be entitled to manage also all the profits generated by the initiative. For the first four interests, it can be noticed that the performance of the ESCo and the PPP initiative coincides since they will touch on aspects that can be reputed part integrally of a REC initiative such as the green reputation of the Municipality and the emission and territory pollution reduction, that must be reached by law even if is the ESCo is entitled to develop the REC and the Municipality do a support role.

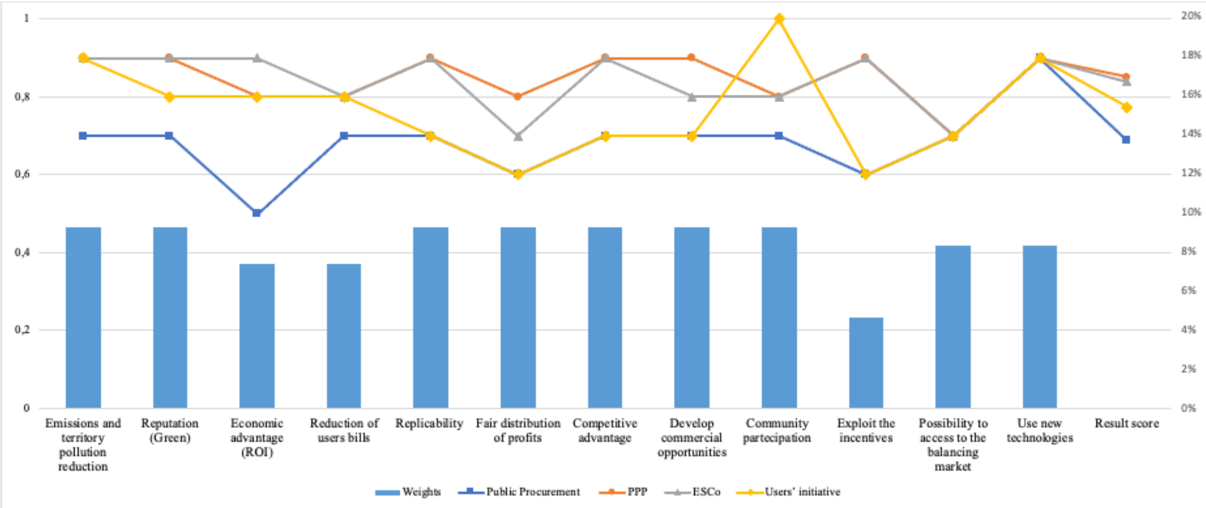


Figure 4.7 –Aggregator sensitivity analysis

Here the final ranking shows the same result, with the difference however that the PPP initiative and the ESCo make the aggregator almost indifferent in contributing to the achievement of its objectives. This is mainly because it has been assumed that they would be responsible for most of the activities and thus help satisfy the interests of the aggregator in a similar way compared to other scenarios. The other scenarios with roughly the same scores for most interests are user initiative and public procurement, as here the role of the aggregator is mainly confined to the technical partner and energy flow management. However, the overall score causes the aggregator to prefer the users' scenario due to the contribution of the community participation goal and the high importance given by the aggregator, which would require more efforts from the Council in case it were the same in charge of sensitizing a population unfamiliar with this type of initiative. This is justified because for the aggregator, even in a configuration in which it should assume only a technical role, user participation is essential, an element inherent in every stakeholder of the REC initiative, as also witnessed by the review literature of chapter 2. The aggregator is typically a private company, an example of an Italian public aggregator is Ener.Bit, that is involved in the "Smart CER" project in the Biella area (Olivero S. 2022), This experience, initially developed ad-hoc in that area, has a good replication potential at Italian national level. For this reason, in general, the economic motivation in this type of initiative becomes important, above all in a scenario where there is also risk sharing and the financing of subsidies, as in the case of the PPP and the ESCo. Since in the Users' initiative the financing activity is the responsibility of the Users, it is evident that this interest for the aggregator will be less satisfied, together with the reduction in reputation and emissions, due to the more superficial role that the aggregator has in the creation and in project development.

3.3 Conclusions

This work has analyzed ex-post which modality to create a residential REC initiative is optimal in the case of the Municipality of Montevarchi. The case study methodology helped in this aim and allowed us to answer the research question: "is the PPP the optimal solution to create the REC in the Italian Municipality of Montevarchi? If yes, in which way?".

The case study analysis was useful to treat this topic since it allows us to analyze and comprehend a phenomenon in its context, using a multiplicity of sources. The secondary sources used were mainly the tender documents, while the primary ones were the semi-structured interviews and surveys submitted to the Mayor of the Municipality and the President of Green Wolf Srl, the aggregator and promoter of the initiative. The case study analysis has been developed with an inductive approach since the research started without any prejudice or personal involvement in the initiative, thing that has brought as much as possible impartial and reliable results. The Montevarchi case is then the first example of an initiative that is born in PPP, making it very important from the research point of view. To analyze this case and answer the research question than has been studied the literature concerning the REC topic and how it has been treated in the literature. This was useful to understand how to proceed, build a solid knowledge of the topic, and facing the evaluation process.

Lode et al. (2021) used the MAMCA methodology applied to the TM to provide an effective practical decision-making tool to actors of a particular territory for the solution of territory-specific energy issues. In this case, however, the case MAMCA is useful to assess if the various stakeholders have chosen the alternative that better fits their interests, and so evaluating an ex-post decision rather to follow the process that has determined it. It is useful to point out that what has been the object of analysis is not the constitution of the REC, also because it hasn't happened yet, but rather an evaluation of the determinants that have led the stakeholders to choose PPP rather than other alternatives. In this study, there are presently three criticalities. Firstly, the evaluation of the scenarios is made through an "Analyst Evaluation" and so the reliability of the results is partially unprecise, and an Experts Evaluation could have given results more precise and credible. Secondly, among the stakeholders, it misses the Users' perspective since the initiative is at a very early stage and they have not yet been identified. For this reason, it is not has been possible to determine how their interest evaluation could have affected the final score of the scenarios. Thirdly, there isn't a way to extend the results in an absolutistic way, since is a unique case and there aren't equal in the Italian context. For this reason, the treated case is an intrinsic case study since there was not possible to compare them with other similar cases. Unfortunately, this aspect makes the outcomes not abstractable and completely usable in other contexts. Further research could solve this kind of problem, making comparisons between different cases and evaluating the criteria made by a team of experts. It should be useful then develop another layer of research that will analyze the results and the consequent degree of satisfaction of the various stakeholder, to also assess the impact of the REC and the reliability of the evaluation instrument.

In addition, this research proposes to encourage the MAMCA implementation in the REC creation process in the Italian context, both by Municipality and other actors interested in this kind of initiative, because it allows ex-ante to determine the best solution to an issue considering all the playing interests of the stakeholders. This issue is also present in the paper of Lode et al. (2021) and allows a solution to emerge directly from the issue, and not make an evaluation of an already present proposal. Overall, can be affirmed that this methodology can be reputed as an optimal solution also to involve preventively the citizens, with a major probability to increase future users' participation and REC awareness, an element that represents the milestone for every peer-to-peer renewable energy project. In conclusion, it is possible to affirm that thanks to the cooperation between a forward-looking Municipality and the active presence of competent private partners, has been designed and then proposed a project of REC in Italy in PPP that, at least theoretically, proposes to meet the needs of the two entities and if properly modelled and approved by ARERA, is destinated to be replicated in every province of the country in the near future.

Bibliography

'History of Electricity. In *Pathways to a Smarter Power System*, 1–27. Elsevier, 2019. https://doi.org/10.1016/B978-0-08-102592-5.00001-6.

Abdelrahman, H.E., M.H. Wahba, H.A. Refaey, M. Moawad, and N.S. Berbish. 'Performance Enhancement of Photovoltaic Cells by Changing Configuration and Using PCM (RT35HC) with Nanoparticles Al2O3'. *Solar Energy* 177 (January 2019): 665–71. https://doi.org/10.1016/j.solener.2018.11.022.

Akbiyikli, R, and D Eaton. 'A COMPARISON OF PFI, BOT, BOO, AND BOOT PROCUREMENT ROUTES…', Research Institute for Built and Human Environment. (Ferris and Munson, n.d.)

Al-Shetwi, Ali Q., M.A. Hannan, Ker Pin Jern, M. Mansur, and T.M.I. Mahlia. 'Grid-Connected Renewable Energy Sources: Review of the Recent Integration Requirements and Control Methods'. *Journal of Cleaner Production* 253 (April 2020): 119831. https://doi.org/10.1016/j.jclepro.2019.119831.

Algarvio, Hugo. 'Management of Local Citizen Energy Communities and Bilateral Contracting in Multi-Agent Electricity Markets'. *Smart Cities* 4, no. 4 (27 November 2021): 1437–53. https://doi.org/10.3390/smartcities4040076.

Ali, Hafiz Muhammad. 'Recent Advancements in PV Cooling and Efficiency Enhancement Integrating Phase Change Materials Based Systems – A Comprehensive Review'. *Solar Energy* 197 (February 2020): 163–98. https://doi.org/10.1016/j.solener.2019.11.075.

Antonopoulos, Ioannis, Valentin Robu, Benoit Couraud, Desen Kirli, Sonam Norbu, Aristides Kiprakis, David Flynn, Sergio Elizondo-Gonzalez, and Steve Wattam. 'Artificial Intelligence and Machine Learning Approaches to Energy Demand-Side Response: A Systematic Review'. *Renewable and Sustainable Energy Reviews* 130 (September 2020): 109899. https://doi.org/10.1016/j.rser.2020.109899.

Argyrou, Maria C., Paul Christodoulides, and Soteris A. Kalogirou. 'Energy Storage for Electricity Generation and Related Processes: Technologies Appraisal and Grid Scale Applications'. *Renewable and Sustainable Energy Reviews* 94 (October 2018): 804–21. https://doi.org/10.1016/j.rser.2018.06.044.

Bahloul, Mohamed, Liam Breathnach, Jerry Cotter, Mohamed Daoud, Aziz Saif, and Shafi Khadem. 'Role of Aggregator in Coordinating Residential Virtual Power Plant in "StoreNet" : A Pilot Project Case Study'. *IEEE Transactions on Sustainable Energy* 13, no. 4 (October 2022): 2148–58. https://doi.org/10.1109/TSTE.2022.3187217.

Bajwa, Dilpreet S., Tyler Peterson, Neeta Sharma, Jamileh Shojaeiarani, and Sreekala G. Bajwa. 'A Review of Densified Solid Biomass for Energy Production'. *Renewable and Sustainable Energy Reviews* 96 (November 2018): 296–305. https://doi.org/10.1016/j.rser.2018.07.040.

Banville, Claude, Maurice Landry, Jean-Marc Martel, and Christèle Boulaire. 'A Stakeholder Approach to MCDA'. *Systems Research and Behavioral Science* 15, no. 1 (January 1998): 15–32. https://doi.org/10.1002/(SICI)1099-1743(199801/02)15:1<15::AID-SRES179>3.0.CO;2-B.

Barnett, Julie, Kate Burningham, Gordon Walker, and Noel Cass. 'Imagined Publics and Engagement around Renewable Energy Technologies in the UK', 2012, 15.

Barroco F.. 'LE COMUNITÀ ENERGETICHE IN ITALIA', 2020, 36.

Baudry, Gino, Cathy Macharis, and Thomas Vallée. 'Range-Based Multi-Actor Multi-Criteria Analysis: A Combined Method of Multi-Actor Multi-Criteria Analysis and Monte Carlo Simulation to Support Participatory Decision Making under Uncertainty'. *European Journal of Operational Research* 264, no. 1 (January 2018): 257–69. https://doi.org/10.1016/j.ejor.2017.06.036.

Baxter, Jamie, Rakhee Morzaria, and Rachel Hirsch. 'A Case-Control Study of Support/Opposition to Wind Turbines: Perceptions of Health Risk, Economic Benefits, and Community Conflict'. *Energy Policy* 61 (October 2013): 931–43. https://doi.org/10.1016/j.enpol.2013.06.050.

Bhatti, Harrison John, and Mike Danilovic. 'Business Model Innovation Approach for Commercializing Smart Grid Systems'. *American Journal of Industrial and Business Management* 08, no. 09 (2018): 2007–51. https://doi.org/10.4236/ajibm.2018.89134.

Bjerkan, Kristin Ystmark, Tom E. Nørbech, and Marianne Elvsaas Nordtømme. 'Incentives for Promoting Battery Electric Vehicle (BEV) Adoption in Norway'. *Transportation Research Part D: Transport and Environment* 43 (March 2016): 169–80. https://doi.org/10.1016/j.trd.2015.12.002.

Caporale, Diana, and Caterina De Lucia. 'Social Acceptance of On-Shore Wind Energy in Apulia Region (Southern Italy)'. *Renewable and Sustainable Energy Reviews* 52 (December 2015): 1378–90. https://doi.org/10.1016/j.rser.2015.07.183.

Carbonara, Nunzia, and Roberta Pellegrino. 'Public-Private Partnerships for Energy Efficiency Projects: A Win-Win Model to Choose the Energy Performance Contracting Structure'. *Journal of Cleaner Production* 170 (January 2018): 1064–75.

Casalicchio, Valeria, Giampaolo Manzolini, Matteo Giacomo Prina, and David Moser. 'From Investment Optimization to Fair Benefit Distribution in Renewable Energy Community Modelling'. *Applied Energy* 310 (March 2022): 118447. https://doi.org/10.1016/j.apenergy.2021.118447.

Cedrick, Bindzi Zogo Emmanuel, and Pr. Wei Long. 'Investment Motivation in Renewable Energy: A PPP Approach'. *Energy Procedia* 115 (June 2017): 229–38. https://doi.org/10.1016/j.egypro.2017.05.021.

Chan, Derek, Mark Cameron, and Younju Yoon. 'Implementationof Micro Energy Grid: A Case Study of a Sustainable Community in China'. *Energy and Buildings* 139 (March 2017): 719–31. https://doi.org/10.1016/j.enbuild.2017.01.055.

Chen, Yen-Haw, Su-Ying Lu, Yung-Ruei Chang, Ta-Tung Lee, and Ming-Che Hu. 'Economic Analysis and Optimal Energy Management Models for Microgrid Systems: A Case Study in Taiwan'. *Applied Energy* 103 (March 2013): 145–54. https://doi.org/10.1016/j.apenergy.2012.09.023.

China Electric Power Research Institute, Dongxia Zhang, Xiaoqing Han, Taiyuan University of Technology, Chunyu Deng, and China Electric Power Research Institute. 'Review on the

Research and Practice of Deep Learning and Reinforcement Learning in Smart Grids'. *CSEE Journal of Power and Energy Systems* 4, no. 3 (24 September 2018): 362–70. https://doi.org/10.17775/CSEEJPES.2018.00520.

Cielo, A., P. Margiaria, P. Lazzeroni, I. Mariuzzo, and M. Repetto. 'Renewable Energy Communities Business Models under the 2020 Italian Regulation'. *Journal of Cleaner Production* 316 (September 2021): 128217. https://doi.org/10.1016/j.jclepro.2021.128217.

Claudia Benanti. '«Energy Performance Contract»: il contratto di rendimento energetico o di prestazione energetica'. *Osservatorio del diritto civile e commerciale*, no. 2 (2017): 403–38. https://doi.org/10.4478/88249.

Codice dei Contratti Pubblici, 2017, art. 165

Conradie, Peter D., Olivia De Ruyck, Jelle Saldien, and Koen Ponnet. 'Who Wants to Join a Renewable Energy Community in Flanders? Applying an Extended Model of Theory of Planned Behaviour to Understand Intent to Participate'. *Energy Policy* 151 (April 2021): 112121. https://doi.org/10.1016/j.enpol.2020.112121.

De luca r., et al., *"Project Financing e partenariato pubblico privato: aspetti normativi e linee guida operative"*. Consiglio Nazionale dei Dottori Commercialisti e degli Esperti Contabili. 2016. Roma.

De_Santoli, L. & De_Santoli, L. (2016) *Smart grid : strategia per la comunità dell'energia su scala urbana.* Milano: Editoriale Delfino.

Decreto Ministeriale of 16 September 2020 del MISE

Després, Jacques, Nouredine Hadjsaid, Patrick Criqui, and Isabelle Noirot. 'Modelling the Impacts of Variable Renewable Sources on the Power Sector: Reconsidering the Typology of Energy Modelling Tools'. *Energy* 80 (February 2015): 486–95. https://doi.org/10.1016/j.energy.2014.12.005.

Di Silvestre, Maria Luisa, Mariano Giuseppe Ippolito, Eleonora Riva Sanseverino, Giuseppe Sciumè, and Antony Vasile. 'Energy Self-Consumers and Renewable Energy Communities in Italy: New Actors of the Electric Power Systems'. *Renewable and Sustainable Energy Reviews* 151 (November 2021): 111565. https://doi.org/10.1016/j.rser.2021.111565.

Directive of the European Parliament and of the Council *2018/2001/EU*

Directive of the European Parliament and of the Council *2019/994/EU*

Directive of the European Parliament and the Council 2014/24/UE of 26th February 2014 on public procurement and repealing Directive 2004/18/EC.

Dl. 12th April 2006, n.163. Code of Public Contracts.

Dl. 18th April 2016, n.50. Code of Public Contracts.

Dl. 4th July 2014, n.102.

Dlgs. 19 Maggio 2020, n.34

Dlgs. 8 Novembre 2021, n.199/2021

Dóci, Gabriella, and Eleftheria Vasileiadou. '"Let's Do It Ourselves" Individual Motivations for Investing in Renewables at Community Level'. *Renewable and Sustainable Energy Reviews* 49 (September 2015): 41–50. https://doi.org/10.1016/j.rser.2015.04.051.

Egidi S., Leonforte a., Nobile V., 2022. The Public-Private Partnership Law Review: Italy - The Law Reviews, n.d., 18.

EMBER. "Global Electricity Review 2022". March 2022.

Engel E., Galetovic A., Fischer R., 2014. *The basics Public Finance of Public-Private Partnerships.* Journal of the European Economic Association.

Erenoğlu, Ayşe Kübra, Ozan Erdinç, and Akın Taşcıkaraoğlu. 'History of Electricity'. In *Pathways to a Smarter Power System*, 1–27. Elsevier, 2019. https://doi.org/10.1016/B978-0-08-102592-5.00001-6.

Eroe K. et al. 2022. "Comunità Rinnovabili: Il ruolo di sole, vento, acqua, terra nel raggiungimento degli obiettivi climatici e lo sviluppo dei nuovi modelli energetici nei territori per una transizione equa e solidale". Legambiente (2022). https://www.comunirinnovabili.it/wp-content/uploads/2022/05/CR2022-2.pdf.

European Commission, 2003. Guidelines for successful public-private partnerships, COM n.d.

European Commission. Joint Research Centre. *Energy Communities: An Overview of Energy and Social Innovation.* LU: Publications Office, 2020. https://data.europa.eu/doi/10.2760/180576.

European PPP Expertise Centre. *Review of the European public-private partnership market in 2021.*2022: European Investment Bank.

Evers, Gerwin, and Maryse M.H. Chappin. 'Knowledge Sharing in Smart Grid Pilot Projects'. *Energy Policy* 143 (August 2020): 111577. https://doi.org/10.1016/j.enpol.2020.111577.

F.G. Reis, Inês, Ivo Gonçalves, Marta A.R. Lopes, and Carlos Henggeler Antunes. 'Business Models for Energy Communities: A Review of Key Issues and Trends'. *Renewable and Sustainable Energy Reviews* 144 (July 2021): 111013. https://doi.org/10.1016/j.rser.2021.111013.

Fabre A., Straub S.. 'The Impact of Public-Private Partnerships (PPPs) in Infrastructure, Health and Education, 2021, 108.

Fasano G., Centi G., Landi M. G., Margiotta F., 2015. *'Linee guida per un contratto Energy Performance Contract secondo il DLgs 102/2014'*, n.d., 32.

Ferris, Michael C, and Todd S Munson. 'GAMS/PATH User Guide Version 4.3', n.d., 62.

Fioriti, Davide, Antonio Frangioni, and Davide Poli. 'Optimal Sizing of Energy Communities with Fair Revenue Sharing and Exit Clauses: Value, Role and Business Model of Aggregators and Users'. *Applied Energy* 299 (October 2021): 117328. https://doi.org/10.1016/j.apenergy.2021.117328.

Foley, A.M., B.P. Ó Gallachóir, J. Hur, R. Baldick, and E.J. McKeogh. 'A Strategic Review of Electricity Systems Models'. *Energy* 35, no. 12 (December 2010): 4522–30. https://doi.org/10.1016/j.energy.2010.03.057.

Gallia, Roberto. 'Il Partenariato Pubblico Privato', 2008, 10.

Garmendia, Eneko, and Sigrid Stagl. 'Public Participation for Sustainability and Social Learning: Concepts and Lessons from Three Case Studies in Europe'. *Ecological Economics* 69, no. 8 (June 2010): 1712–22. https://doi.org/10.1016/j.ecolecon.2010.03.027.

Gharieh, Kaveh, and Mohsen A Jafari. 'Public-Private Partnership (PPP) Financing Model for Micro-Grids', n.d., 10.

Ghiani, Emilio, Andrea Giordano, Andrea Nieddu, Luca Rosetti, and Fabrizio Pilo. 'Planning of a Smart Local Energy Community: The Case of Berchidda Municipality (Italy)'. *Energies* 12, no. 24 (5 December 2019): 4629. https://doi.org/10.3390/en12244629.

Ghosh, Subarto Kumar, Tushar Kanti Roy, Md Abu Hanif Pramanik, Ajay Krishno Sarkar, and Gian Franco Cartei. 'I freni negli interventi infrastrutturali. Strumenti di partenariato pubblico-privato e qualità di redazione normativa del Codice dei contratti pubblici'. *Analisi Giuridica dell'Economia*, no. 1 (2020): 239–54. https://doi.org/10.1433/98452.

Giorgio, Carla, Giorgia Marinuzzi, Walter Tortorella, IFEL-Fondazione Anci, and Marco Nicolai. 'Questo Documento di analisi è a cura di', n.d., 38.

Green Wolf Srl; Gruppo SIM TEL, 2022. Municipality of Montevarchi. "REALIZZAZIONE MEDIANTE PROJECT FINANCING DI IMPIANTI DI PRODUZIONE DA FONTI ENERGETICHE RINNOVABILI E DI UNA COMUNITÀ ENERGETICA RINNOVABILE NEL COMUNE DI MONTEVARCHI - CIG 9346785AFA". "CONVENZIONE". Document number 4.1 and Attachments 5-8. Municipality of Montevarchi Website. Publication date 22/08/2022. Available at https://www.comune.montevarchi.ar.it [Accessed 27/09/2022]

Green Wolf Srl; Gruppo SIM TEL, 2022. Municipality of Montevarchi. “REALIZZAZIONE MEDIANTE PROJECT FINANCING DI IMPIANTI DI PRODUZIONE DA FONTI ENERGETICHE RINNOVABILI E DI UNA COMUNITÀ ENERGETICA RINNOVABILE NEL COMUNE DI MONTEVARCHI - CIG 9346785AFA”. “PIANO ECONOMICO E FINANZIARIO”. Documents number 5.1-5.3. Municipality of Montevarchi Website. Publication date 22/08/2022. Available at https://www.comune.montevarchi.ar.it [Accessed 27/09/2022]

Green Wolf Srl; Gruppo SIM TEL, 2022. Municipality of Montevarchi. “REALIZZAZIONE MEDIANTE PROJECT FINANCING DI IMPIANTI DI PRODUZIONE DA FONTI ENERGETICHE RINNOVABILI E DI UNA COMUNITÀ ENERGETICA RINNOVABILE NEL COMUNE DI MONTEVARCHI - CIG 9346785AFA”. “PROGETTO DI FATTIBILITÁ TECNICA ED ECONOMICA E DEL SERVIZIO E DELLA GESTIONE”. Document number 3.1-3.5. Municipality of Montevarchi Website. Publication date 22/08/2022. Available at https://www.comune.montevarchi.ar.it [Accessed 27/09/2022]

Gui, Emi Minghui, Iain MacGill, and Regina Betz. ‘Community Microgrid Investment Planning: A Conceptual Framework’. In *2018 IEEE International Smart Cities Conference (ISC2)*, 1–5. Kansas City, MO, USA: IEEE, 2018. https://doi.org/10.1109/ISC2.2018.8656707.

Guo, Shaopeng, Qibin Liu, Jie Sun, and Hongguang Jin. ‘A Review on the Utilization of Hybrid Renewable Energy’. *Renewable and Sustainable Energy Reviews* 91 (August 2018): 1121–47. https://doi.org/10.1016/j.rser.2018.04.105.

Gür, Turgut M. ‘Review of Electrical Energy Storage Technologies, Materials and Systems: Challenges and Prospects for Large-Scale Grid Storage’. *Energy & Enviromental Science* 11, no. 10 (2018): 2696–2767. https://doi.org/10.1039/C8EE01419A.

H.R.5376 - 117th Congress (2021-2022): Inflation Reduction Act of 2022.

Heaslip, Eimear, Gabriel J. Costello, and John Lohan. ‘Assessing Good-Practice Frameworks for the Development of Sustainable Energy Communities in Europe: Lessons from Denmark and Ireland’. *Journal of Sustainable Development of Energy, Water and Environment Systems* 4, no. 3 (September 2016): 307–19. https://doi.org/10.13044/j.sdewes.2016.04.0024.

Heuninckx, Shary, Geert te Boveldt, Cathy Macharis, and Thierry Coosemans. ‘Stakeholder Objectives for Joining an Energy Community: Flemish Case Studies’. *Energy Policy* 162 (March 2022): 112808. https://doi.org/10.1016/j.enpol.2022.112808.

Hewitt, Richard J., Nicholas Bradley, Andrea Baggio Compagnucci, Carla Barlagne, Andrzej Ceglarz, Roger Cremades, Margaret McKeen, Ilona M. Otto, and Bill Slee. ‘Social Innovation in Community Energy in Europe: A Review of the Evidence’. *Frontiers in Energy Research* 7 (5 April 2019): 31. https://doi.org/10.3389/fenrg.2019.00031.

Huang, He & Lebeau, Philippe & Macharis, Cathy. (2020). The Multi-Actor Multi-Criteria Analysis (MAMCA): New Software and New Visualizations.

Iazzolino, Gianpaolo, Nicola Sorrentino, Daniele Menniti, Anna Pinnarelli, Monica De Carolis, and Luca Mendicino. 'Energy Communities and Key Features Emerged from Business Models Review'. *Energy Policy* 165 (June 2022): 112929. https://doi.org/10.1016/j.enpol.2022.112929.

Iliana Ivanova. 'Public Private Partnerships in the EU: Widespread Shortcomings and Limited Benefits', 2018, 79.

Inganäs, Olle. 'Organic Photovoltaics over Three Decades'. *Advanced Materials* 30, no. 35 (August 2018): 1800388. https://doi.org/10.1002/adma.201800388.

Iossa, Elisabetta, and David Martimort. 'The Simple Microeconomics of Public-Private Partnerships: The Simple Microeconomics of PPP'. *Journal of Public Economic Theory* 17, no. 1 (February 2015): 4–48. https://doi.org/10.1111/jpet.12114.

Islam, Md Tasbirul, Nazmul Huda, A.B. Abdullah, and R. Saidur. 'A Comprehensive Review of State-of-the-Art Concentrating Solar Power (CSP) Technologies: Current Status and Research Trends'. *Renewable and Sustainable Energy Reviews* 91 (August 2018): 987–1018. https://doi.org/10.1016/j.rser.2018.04.097.

Istat 2022. Available at:

http://dati.istat.it/viewhtml.aspx?il=blank&vh=0000&vf=0&vcq=1100&graph=0&view-metadata=1&lang=it&QueryId=11944

Jamal, Taskin, and Sayedus Salehin. 'Hybrid Renewable Energy Sources Power Systems'. In *Hybrid Renewable Energy Systems and Microgrids*, 179–214. Elsevier, 2021. https://doi.org/10.1016/B978-0-12-821724-5.00010-6.

Jank, Reinhard. 'Annex 51: Case Studies and Guidelines for Energy Efficient Communities'. *Energy and Buildings* 154 (November 2017): 529–37. https://doi.org/10.1016/j.enbuild.2017.08.074.

Jately, Vibhu, Balaji Venkateswaran V., Stefan Azzopardi, and Brian Azzopardi. 'Design and Performance Investigation of a Pilot Micro-Grid in the Mediterranean: MCAST Case Study'. *Energies* 14, no. 20 (19 October 2021): 6846. https://doi.org/10.3390/en14206846.

Jenkins, Kirsten, Darren McCauley, Raphael Heffron, Hannes Stephan, and Robert Rehner. 'Energy Justice: A Conceptual Review'. *Energy Research & Social Science* 11 (January 2016): 174–82. https://doi.org/10.1016/j.erss.2015.10.004.

Kaiser, Serena, Mariana Oliveira, Chiara Vassillo, Giuseppe Orlandini, and Amalia Zucaro. 'Social and Environmental Assessment of a Solidarity Oriented Energy Community: A Case-Study in San Giovanni a Teduccio, Napoli (IT)'. *Energies* 15, no. 4 (20 February 2022): 1557. https://doi.org/10.3390/en15041557.

Karami, Mahdi, and Reinhard Madlener. 'Business Models for Peer-to-Peer Energy Trading in Germany Based on Households' Beliefs and Preferences'. *Applied Energy* 306 (January 2022): 118053. https://doi.org/10.1016/j.apenergy.2021.118053.

Kaschub, Thomas, Patrick Jochem, and Wolf Fichtner. 'Solar Energy Storage in German Households: Profitability, Load Changes and Flexibility'. *Energy Policy* 98 (November 2016): 520–32. https://doi.org/10.1016/j.enpol.2016.09.017.

Katsaprakakis, Dimitris Al., Antonia Proka, Dimitris Zafirakis, Markos Damasiotis, Panos Kotsampopoulos, Nikos Hatziargyriou, Eirini Dakanali, George Arnaoutakis, and Dimitrios Xevgenos. 'Greek Islands' Energy Transition: From Lighthouse Projects to the Emergence of Energy Communities'. *Energies* 15, no. 16 (18 August 2022): 5996. https://doi.org/10.3390/en15165996.

Keck, Felix, and Manfred Lenzen. 'Drivers and Benefits of Shared Demand-Side Battery Storage – an Australian Case Study'. *Energy Policy* 149 (February 2021): 112005. https://doi.org/10.1016/j.enpol.2020.112005.

Klöpffer, Walter. 'Life Cycle Assessment: From the Beginning to the Current State'. *Environmental Science and Pollution Research* 4, no. 4 (December 1997): 223–28. https://doi.org/10.1007/BF02986351.

Koliba, Christopher, Mercy DeMenno, Nancy Brune, and Asim Zia. 'The Salience and Complexity of Building, Regulating, and Governing the Smart Grid: Lessons from a Statewide Public–Private Partnership'. *Energy Policy* 74 (November 2014): 243–52. https://doi.org/10.1016/j.enpol.2014.09.013.

Kourtit, Karima, Cathy Macharis, and Peter Nijkamp. 'A Multi-Actor Multi-Criteria Analysis of the Performance of Global Cities'. *Applied Geography* 49 (May 2014): 24–36. https://doi.org/10.1016/j.apgeog.2013.09.006.

Kumar, Rajeev Ranjan, and Kumar Alok. 'Adoption of Electric Vehicle: A Literature Review and Prospects for Sustainability'. *Journal of Cleaner Production* 253 (April 2020): 119911. https://doi.org/10.1016/j.jclepro.2019.119911.

L.29 Febbraio 2020, n.8/2020

Lehtonen, Markku, and Sheridan Nye. 'History of Electricity Network Control and Distributed Generation in the UK and Western Denmark'. *Energy Policy* 37, no. 6 (June 2009): 2338–45. https://doi.org/10.1016/j.enpol.2009.01.026.

Li, Li Wen, Janine Birmele, Harald Schaich, and Werner Konold. 'Transitioning to Community-Owned Renewable Energy: Lessons from Germany'. *Procedia Environmental Sciences* 17 (2013): 719–28. https://doi.org/10.1016/j.proenv.2013.02.089.

Libro Verde relativo ai partenariati pubblico-privati ed al diritto comunitario degli appalti pubblici e delle concessioni, 2004. COM 327, finale.

Liebe Moritz, and David Howarth. 'The European Investment Bank as Policy Entrepreneur and the Promotion of Public-Private Partnerships'. *New Political Economy* 25, no. 2 (23 February 2020): 195–212. https://doi.org/10.1080/13563467.2019.1586862.

Liebe, Moritz, and David Howarth. 'The European Investment Bank as Policy Entrepreneur and the Promotion of Public-Private Partnerships'. *New Political Economy* 25, no. 2 (23 February 2020): 195–212. https://doi.org/10.1080/13563467.2019.1586862.

Lienhoop, Nele. 'Acceptance of Wind Energy and the Role of Financial and Procedural Participation: An Investigation with Focus Groups and Choice Experiments'. *Energy Policy* 118 (July 2018): 97–105. https://doi.org/10.1016/j.enpol.2018.03.063.

Lode, Maria Luisa, Geert te Boveldt, Cathy Macharis, and Thierry Coosemans. 'Application of Multi-Actor Multi-Criteria Analysis for Transition Management in Energy Communities'. *Sustainability* 13, no. 4 (7 February 2021): 1783. https://doi.org/10.3390/su13041783.

Lode, Maria Luisa, Geert te Boveldt, Cathy Macharis, and Thierry Coosemans. 'Application of Multi-Actor Multi-Criteria Analysis for Transition Management in Energy Communities'. *Sustainability* 13, no. 4 (7 February 2021): 1783. https://doi.org/10.3390/su13041783.ù

Lode, Maria Luisa, Shary Heuninckx, Geert te Boveldt, Cathy Macharis, and Thierry Coosemans. 'Designing Successful Energy Communities: A Comparison of Seven Pilots in Europe Applying the Multi-Actor Multi-Criteria Analysis'. *Energy Research & Social Science* 90 (August 2022): 102671. https://doi.org/10.1016/j.erss.2022.102671.

Lode, Maria Luisa, Shary Heuninckx, Geert te Boveldt, Cathy Macharis, and Thierry Coosemans. 'Designing Successful Energy Communities: A Comparison of Seven Pilots in Europe Applying the Multi-Actor Multi-Criteria Analysis'. *Energy Research & Social Science* 90 (August 2022): 102671. https://doi.org/10.1016/j.erss.2022.102671.

Loorbach, Derk, Niki Frantzeskaki, and Roebin Lijnis Huffenreuter. 'Transition Management: Taking Stock from Governance Experimentation'. *Journal of Corporate Citizenship* 2015, no. 58 (1 June 2015): 48–66. https://doi.org/10.9774/GLEAF.4700.2015.ju.00008.

Loorbach, Derk, Niki Frantzeskaki, and Roebin Lijnis Huffenreuter. 'Transition Management: Taking Stock from Governance Experimentation'. *Journal of Corporate Citizenship* 2015, no. 58 (1 June 2015): 48–66. https://doi.org/10.9774/GLEAF.4700.2015.ju.00008.

Lowitzsch, Jens. 'Consumer Stock Ownership Plans (CSOPs)—The Prototype Business Model for Renewable Energy Communities'. *Energies* 13, no. 1 (25 December 2019): 118. https://doi.org/10.3390/en13010118.

Lu, Zhiming, Yan Gao, and Chuanbo Xu. 'Sustainability Evaluation of Public–Private Partnership Microgrid Considering Uncertainty and Risk Preference'. *Sustainable Energy, Grids and Networks* 26 (June 2021): 100426. https://doi.org/10.1016/j.segan.2020.100426.

Lund, John W., and Aniko N. Toth. 'Direct Utilization of Geothermal Energy 2020 Worldwide Review'. *Geothermics* 90 (February 2021): 101915. https://doi.org/10.1016/j.geothermics.2020.101915.

Lüth, Alexandra, Jan Martin Zepter, Pedro Crespo del Granado, and Ruud Egging. 'Local Electricity Market Designs for Peer-to-Peer Trading: The Role of Battery Flexibility'. *Applied Energy* 229 (November 2018): 1233–43. https://doi.org/10.1016/j.apenergy.2018.08.004.

Macharis, Cathy, Astrid de Witte, and Jeroen Ampe. 'The Multi-Actor, Multi-Criteria Analysis Methodology (MAMCA) for the Evaluation of Transport Projects: Theory and Practice'. *Journal of Advanced Transportation* 43, no. 2 (April 2009): 183–202. https://doi.org/10.1002/atr.5670430206.

Macharis, Cathy, Astrid De Witte, and Laurence Turcksin. 'The Multi-Actor Multi-Criteria Analysis (MAMCA) Application in the Flemish Long-Term Decision Making Process on Mobility and Logistics'. *Transport Policy* 17, no. 5 (September 2010): 303–11. https://doi.org/10.1016/j.tranpol.2010.02.004.

Macharis, Cathy, Laurence Turcksin, and Kenneth Lebeau. 'Multi Actor Multi Criteria Analysis (MAMCA) as a Tool to Support Sustainable Decisions: State of Use'. *Decision Support Systems* 54, no. 1 (December 2012): 610–20. https://doi.org/10.1016/j.dss.2012.08.008.

Maere d'Aertrycke, Gauthier de, Yves Smeers, Hugues de Peufeilhoux, and Pierre-Laurent Lucille. 'The Role of Electrification in the Decarbonization of Central-Western Europe'. *Energies* 13, no. 18 (19 September 2020): 4919. https://doi.org/10.3390/en13184919.

Mahzouni, Arian. 'The Role of Institutional Entrepreneurship in Emerging Energy Communities: The Town of St. Peter in Germany'. *Renewable and Sustainable Energy Reviews* 107 (June 2019): 297–308. https://doi.org/10.1016/j.rser.2019.03.011.

Martiniello, L., and S. Saracchi. 'PPP and Cold Infrastructure: A Comparison between Different Procedures'. *European Procurement & Public Private Partnership Law Review* 2, no. 2 (2007): 8. https://doi.org/10.21552/EPPPL/2007/2/56.

Mazur, Jolanta, and Piotr Zaborek. 'Validating Dart Model'. *International Journal of Management and Economics* 44, no. 1 (1 December 2014): 106–25. https://doi.org/10.1515/ijme-2015-0012.

Mazzantini S., et al., 2022. '*Opportunities and Challenges of Energy Performance Contracting in the Italian Market for Energy Efficiency Services.'* IOP Conference Series: Earth and Environmental Science 1073, no.: 012012. https://doi.org/10.1088/1755-1315/1073/1/012012.

McGovern, Gerard. 'Capturing Community Value in Civic Energy Business Model Design'. *Energy Policy* 156 (September 2021): 112468. https://doi.org/10.1016/j.enpol.2021.112468.

Md. Apel Mahmud. 'An Energy Management System-Based Control Strategy for DC Microgrids with Dual Energy Storage Systems'. *Energies* 13, no. 11 (10 June 2020): 2992.

Meitern, Maarja. 'Does Access to Regulative Exemption Reduce Barriers for Energy Communities? A Dutch Case Study'. *Sustainability* 14, no. 9 (6 May 2022): 5608. https://doi.org/10.3390/su14095608.

Mihailova, Darja, Iljana Schubert, Paul Burger, and Morgane M.C. Fritz. 'Exploring Modes of Sustainable Value Co-Creation in Renewable Energy Communities'. *Journal of Cleaner Production* 330 (January 2022): 129917. https://doi.org/10.1016/j.jclepro.2021.129917.

Moncecchi Matteo, Stefano Meneghello, and Marco Merlo. 'A Game Theoretic Approach for Energy Sharing in the Italian Renewable Energy Communities'. *Applied Sciences* 10, no. 22 (18 November 2020): 8166. https://doi.org/10.3390/app10228166.

Moncecchi Matteo, Stefano Meneghello, and Marco Merlo. 'Energy Sharing in Renewable Energy Communities: The Italian Case'. In *2020 55th International Universities Power Engineering Conference (UPEC)*, 1–6. Torino, Italy: IEEE, 2020. https://doi.org/10.1109/UPEC49904.2020.9209813.

Municipality of Montevarchi, 2022. REALIZZAZIONE MEDIANTE PROJECT FINANCING DI IMPIANTI DI PRODUZIONE DA FONTI ENERGETICHE RINNOVABILI E DI UNA COMUNITÀ ENERGETICA RINNOVABILE NEL COMUNE DI MONTEVARCHI - CIG 9346785AFA". "DISCIPLINARE DI GARA". Publication date 22/08/2022. Available at https://www.comune.montevarchi.ar.it [Accessed 27/09/2022]

Musall, Fabian David, and Onno Kuik. 'Local Acceptance of Renewable Energy—A Case Study from Southeast Germany'. *Energy Policy* 39, no. 6 (June 2011): 3252–60. https://doi.org/10.1016/j.enpol.2011.03.017.

Mustika, Alyssa Diva, Rémy Rigo-Mariani, Vincent Debusschere, and Amaury Pachurka. 'New Members Selection for the Expansion of Energy Communities'. *Sustainability* 14, no. 18 (8 September 2022): 11257. https://doi.org/10.3390/su141811257.

Naderifar, Mahin, Hamideh Goli, and Fereshteh Ghaljaie. 'Snowball Sampling: A Purposeful Method of Sampling in Qualitative Research'. *Strides in Development of Medical Education* 14, no. 3 (30 September 2017). https://doi.org/10.5812/sdme.67670.

OECD, 2017. Getting infrastructure Right: the Ten Key Governance Challenges and Policy Options. 2017: OECD

Olivero, Seraio, Emilio Ghiani, and Gian Luca Rosetti. 'The First Italian Renewable Energy Community of Magliano Alpi'. In *2021 IEEE 15th International Conference on Compatibility, Power Electronics and Power Engineering (CPE-POWERENG)*, 1–6. Florence, Italy: IEEE, 2021. https://doi.org/10.1109/CPE-POWERENG50821.2021.9501073.

Pallonetto, Fabiano, Mattia De Rosa, Federico Milano, and Donal P. Finn. 'Demand Response Algorithms for Smart-Grid Ready Residential Buildings Using Machine Learning Models'. *Applied Energy* 239 (April 2019): 1265–82. https://doi.org/10.1016/j.apenergy.2019.02.020.

Paradisi I.,. "Il Partenariato Pubblico Privato: inquadramento normativo".2017. *Dipartimento della Funzione Pubblica.*

Perea-Moreno, Miguel-Angel, Esther Samerón-Manzano, and Alberto-Jesus Perea-Moreno. 'Biomass as Renewable Energy: Worldwide Research Trends'. *Sustainability* 11, no. 3 (7 February 2019): 863. https://doi.org/10.3390/su11030863.

Pereira, Helder, Bruno Ribeiro, Luís Gomes, and Zita Vale. 'CECOS: A Centralized Management Platform Supported by Distributed Services to Represent and Manage Resources Aggregation Entities and Its End-Users in a Smart Grid Context'. *IFAC-PapersOnLine* 55, no. 9 (2022): 309–14. https://doi.org/10.1016/j.ifacol.2022.07.054.

Piano Nazionale di Ripresa e Resilienza, 2021.

Planko, Julia, Maryse M.H. Chappin, Jacqueline M. Cramer, and Marko P. Hekkert. 'Managing Strategic System-Building Networks in Emerging Business Fields: A Case Study of the Dutch Smart Grid Sector'. *Industrial Marketing Management* 67 (November 2017): 37–51. https://doi.org/10.1016/j.indmarman.2017.06.010.

Plötz, Patrick, Uta Schneider, Joachim Globisch, and Elisabeth Dütschke. 'Who Will Buy Electric Vehicles? Identifying Early Adopters in Germany'. *Transportation Research Part A: Policy and Practice* 67 (September 2014): 96–109. https://doi.org/10.1016/j.tra.2014.06.006.

Porté-Agel, Fernando, Majid Bastankhah, and Sina Shamsoddin. 'Wind-Turbine and Wind-Farm Flows: A Review'. *Boundary-Layer Meteorology* 174, no. 1 (January 2020): 1–59. https://doi.org/10.1007/s10546-019-00473-0.

Priessner, Alfons, Robert Sposato, and Nina Hampl. 'Predictors of Electric Vehicle Adoption: An Analysis of Potential Electric Vehicle Drivers in Austria'. *Energy Policy* 122 (November 2018): 701–14. https://doi.org/10.1016/j.enpol.2018.07.058.

Private Participation in Infrastructure (PPI) - World Bank Group [online].

N.d. R.D. 16th March 1942, n. 262.

Refaat, Shady S., Omar Ellabban, Sertac Bayhan, Haitham Abu-Rub, Frede Blaabjerg, and Miroslav M. Begovic. *Smart Grid and Enabling Technologies*. 1st ed. Wiley, 2021. https://doi.org/10.1002/9781119422464.

Regional Administrative Court of Milan, 1st April 2019, n.646

Regional Law 10 november 2020, n. 25

Regional Law 11 june 2021, n. 10

Regional Law 17 may 2022, n. 8

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Regional Law 5 july 2022, n. 16

Regional Law Deliberation n. 6/20 of 25.02.2022

Regional Law Draft Law 74/XVI

Renaissance, 2022. Project Overview [online]. Available at <https://www.renaissance-h2020.eu/about/> [13/12/2022]

Resolution 318/2020/R ARERA

Ringkjøb, Hans-Kristian, Peter M. Haugan, and Ida Marie Solbrekke. 'A Review of Modelling Tools for Energy and Electricity Systems with Large Shares of Variable Renewables'.

Renewable and Sustainable Energy Reviews 96 (November 2018): 440–59. https://doi.org/10.1016/j.rser.2018.08.002.

Rossi, Federico, Miguel Heleno, Riccardo Basosi, and Adalgisa Sinicropi. 'LCA Driven Solar Compensation Mechanism for Renewable Energy Communities: The Italian Case'. *Energy* 235 (November 2021): 121374. https://doi.org/10.1016/j.energy.2021.121374.

Roversi, Rossella, Andrea Boeri, Serena Pagliula, and Giulia Turci. 'Energy Community in Action—Energy Citizenship Contract as Tool for Climate Neutrality'. *Smart Cities*, 2022, 24.

Ryszawska, Bożena, Magdalena Rozwadowska, Roksana Ulatowska, Marcin Pierzchała, and Piotr Szymański. 'The Power of Co-Creation in the Energy Transition—DART Model in Citizen Energy Communities Projects'. *Energies* 14, no. 17 (25 August 2021): 5266. https://doi.org/10.3390/en14175266.

Sasaki, Tsuyoshi, Yoshio Ukyo, and Petr Novák. 'Memory Effect in a Lithium-Ion Battery'. *Nature Materials* 12, no. 6 (June 2013): 569–75. https://doi.org/10.1038/nmat3623.

Schär, Sebastian, and Jutta Geldermann. 'Adopting Multiactor Multicriteria Analysis for the Evaluation of Energy Scenarios'. *Sustainability* 13, no. 5 (1 March 2021): 2594. https://doi.org/10.3390/su13052594.

Schoor, Tineke van der, and Bert Scholtens. 'Power to the People: Local Community Initiatives and the Transition to Sustainable Energy'. *Renewable and Sustainable Energy Reviews* 43 (March 2015): 666–75. https://doi.org/10.1016/j.rser.2014.10.089.

Sequenza dei conti: Dati Istat [online]. (September 2022). N.d. Istat.

Steffen, Bjarne. 'The Importance of Project Finance for Renewable Energy Projects'. *Energy Economics* 69 (January 2018): 280–94. https://doi.org/10.1016/j.eneco.2017.11.006.

Tan, Kang Miao, Thanikanti Sudhakar Babu, Vigna K. Ramachandaramurthy, Padmanathan Kasinathan, Sunil G. Solanki, and Shangari K. Raveendran. 'Empowering Smart Grid: A Comprehensive Review of Energy Storage Technology and Application with Renewable Energy Integration'. *Journal of Energy Storage* 39 (July 2021): 102591. https://doi.org/10.1016/j.est.2021.102591.

THE WORLD BANK, 2021. Private Participation in Infrastructure. *The World Bank. 2021*

Thomond, P, and F Lettice. 'Disruptive Innovation Explored', 2002, 4.

Triantis, John E. *Project Finance for Business Development*. Hoboken, NJ, USA: John Wiley & Sons, Inc., 2018. https://doi.org/10.1002/9781119486114.

Tricarico, Luca. 'Is Community Earning Enough? Reflections on Engagement Processes and Drivers in Two Italian Energy Communities'. *Energy Research & Social Science* 72 (February 2021): 101899. https://doi.org/10.1016/j.erss.2020.101899.

Turcksin, Laurence, Cathy Macharis, Kenneth Lebeau, Faycal Boureima, Joeri Van Mierlo, Svend Bram, Jacques De Ruyck, et al. 'A Multi-Actor Multi-Criteria Framework to Assess the Stakeholder Support for Different Biofuel Options: The Case of Belgium'. *Energy Policy* 39, no. 1 (January 2011): 200–214. https://doi.org/10.1016/j.enpol.2010.09.033.

Tushar, Wayes, Tapan Kumar Saha, Chau Yuen, David Smith, and H. Vincent Poor. 'Peer-to-Peer Trading in Electricity Networks: An Overview'. *IEEE Transactions on Smart Grid* 11, no. 4 (July 2020): 3185–3200. https://doi.org/10.1109/TSG.2020.2969657.

UNEP, 2020. Guidelines for Social Life Cycle Assessment of Products and Organizations 2020. Benoît Norris, C., Traverso, M., Neugebauer, S., Ekener, E., Schaubroeck, T., Russo Garrido, S., Berger, M., Valdivia, S., Lehmann, A., Finkbeiner, M., Arcese, G. (eds.). United Na- tions Environment Programme (UNEP).

United Nation. "Transforming our world: the 2030 agenda for sustainable development". 2015

Valera-Medina, A, H Xiao, M Owen-Jones, W.I.F. David, and P.J. Bowen. 'Ammonia for Power'. *Progress in Energy and Combustion Science* 69 (November 2018): 63–102. https://doi.org/10.1016/j.pecs.2018.07.001.

Vernay, Anne-Lorène, and Carine Sebi. 'Energy Communities and Their Ecosystems: A Comparison of France and the Netherlands'. *Technological Forecasting and Social Change* 158 (September 2020): 120123. https://doi.org/10.1016/j.techfore.2020.120123.

Viti, Stefano, Andrea Lanzini, Francesco Demetrio Minuto, Matteo Caldera, and Romano Borchiellini. 'Techno-Economic Comparison of Buildings Acting as Single-Self Consumers or as Energy Community through Multiple Economic Scenarios'. *Sustainable Cities and Society* 61 (October 2020): 102342. https://doi.org/10.1016/j.scs.2020.102342.

Volpato, Gabriele, Gianluca Carraro, Marco Cont, Piero Danieli, Sergio Rech, and Andrea Lazzaretto. 'General Guidelines for the Optimal Economic Aggregation of Prosumers in Energy Communities'. *Energy* 258 (November 2022): 124800.https://doi.org/10.1016/j.energy.2022.124800.

Waal, Esther C. van der. 'Local Impact of Community Renewable Energy: A Case Study of an Orcadian Community-Led Wind Scheme'. *Energy Policy* 138 (March 2020): 111193. https://doi.org/10.1016/j.enpol.2019.111193.

Wang, Fei, Xinxin Ge, Peng Yang, Kangping Li, Zengqiang Mi, Pierluigi Siano, and Neven Duić. 'Day-Ahead Optimal Bidding and Scheduling Strategies for DER Aggregator Considering Responsive Uncertainty under Real-Time Pricing'. *Energy* 213 (December 2020): 118765. https://doi.org/10.1016/j.energy.2020.118765.

Xiang, Wanchun, and Wolfgang Tress. 'Review on Recent Progress of All-Inorganic Metal Halide Perovskites and Solar Cells'. *Advanced Materials* 31, no. 44 (November 2019): 1902851. https://doi.org/10.1002/adma.201902851.

Xin, Liguo, Manzoor Ahmad, and Muntasir Murshed. 'Toward Next-Generation Green Solar Cells and Environmental Sustainability: Impact of Innovation in Photovoltaic Energy Generation, Distribution, or Transmission-Related Technologies on Environmental Sustainability in the

United States'. *Environmental Science and Pollution Research* 29, no. 59 (December 2022): 89662–80. https://doi.org/10.1007/s11356-022-21953-w.

Xue, Yan, Carmel Margaret Lindkvist, and Alenka Temeljotov-Salaj. 'Barriers and Potential Solutions to the Diffusion of Solar Photovoltaics from the Public-Private-People Partnership Perspective – Case Study of Norway'. *Renewable and Sustainable Energy Reviews* 137 (March 2021): 110636. https://doi.org/10.1016/j.rser.2020.110636.

Ye, Feng, Yi Qian, and Rose Qingyang Hu. *Smart Grid Communication Infrastructures: Big Data, Cloud Computing, and Security*. Hoboken, NJ: John Wiley & Sons, 2018.

Zatti, Matteo, Matteo Moncecchi, Marco Gabba, Alberto Chiesa, Filippo Bovera, and Marco Merlo. 'Energy Communities Design Optimization in the Italian Framework'. *Applied Sciences* 11, no. 11 (4 June 2021): 5218. https://doi.org/10.3390/app11115218.

Interviews and Questionnaires

Olivero S., 2022. *Interview at the Head of Business&Finance Innovation at the Energy Center of the Politecnico di Torino* released to Alberto Zago [online] in date 17/09/2022

Martini S. C. and Longo A., 2022. *Interview at the Municipality of Montevarchi* released to Zago Alberto [online] in date 27/09/2022

Martini S. C. and Longo A., 2022. *Questionnaire sent by the Municipality of Montevarchi* released to Zago Alberto [online] in date 16/11/2022

Ferrero P. and Tucci M., 2022. *Interview at Green Wolf Srl* released to Zago Alberto [online] in date 18/10/2022

Bonino S. and Tucci M. 2022. *Questionnaire sent Green Wolf Srl* released to Zago Alberto [online] in date 29/11/2022