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Review

Mapping of Energy Community Development in Europe: State of the Art and Research Directions

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Abstract: Within the framework of defining a new energy paradigm to address climate change and other global challenges, the energy community model is gaining interest in several countries, especially in Europe. This article analyses the literature and experiences of organisational forms that fall under the definition of energy communities in a broad sense, in relation to their ability to bring improvements to the social, environmental and economic dimensions, and to ensure durability and replicability. The main elements that constitute a complete, albeit simplified, model of energy community are identified and analysed. The legislative and regulatory frameworks, technologies and social innovation frameworks, identified here as enabling elements, are discussed, as well as the elements of the energy community business models and the impacts generated at the environmental and energy, economic and social levels. The transformation potential of energy communities is confirmed as more than promising. However, in order to develop as a sustainable and replicable model capable of achieving social and environmental goals, as well as economic stability, further significant research and experimentation, following a cross-sectoral and multidisciplinary approach and strong political leadership, are needed.

Keywords: energy communities; renewables; energy democracy; sustainability

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1. Introduction

Climate change is requiring a radical shift of the current energy system, and several countries are setting decarbonisation policies to decrease their dependence on fossil fuels. Given the urgency of low-carbon targets, to be reached without affecting the security and resilience of the energy systems, the United Nations have identified the need to "Ensure access to affordable, reliable, sustainable and modern energy for all" as one of 17 Sustainable Development Goals to be achieved in the 2030 Agenda for Sustainable Development [1]. Finalised in 2015 by the majority of governments, the Paris agreement [2], with the subsequent revision set at the Conference of Parties (COP26) in 2021 [3], establishes the targets for the reduction in greenhouse gases (GHGs) and the inclusion of renewable energies. At the European level, the "Clean energy for all Europeans package" is the implementation mechanism adopted by the European Union (EU) in 2019 to achieve the Paris agreement's objectives, in line with the European Green Deal targets [4,5].

In this framework, to meet the global and local challenges for developing sustainable energy systems, the definition of a new "energy paradigm" is necessary. In order to ensure efficient and low-impact systems, the energy needed to produce services and goods and to perform activities should have the lowest possible GHG emissions and impacts on the quality of the natural environment, health, and related areas; make use of renewable resources, both sources and materials with a recycling-oriented approach; and make use of high-efficiency technologies. These conditions would allow to respond to a number of issues, including global warming, pollution, loss of biodiversity, finite resources and raw materials. To comply with the other dimensions of sustainability, energy systems must combine economic and social models capable of ensuring a conscious use of energy and compliance with the principles of energy justice (EJ) [6], energy democracy (ED) [7] and energy citizenship [8], as envisioned in EU programmes [5,9,10]. These principles are political, social and cultural concepts tightly connected with an increased awareness of a need for a rapid but also fair and inclusive energy transition [11].

The approach known as ASI (from avoid/reduce–shift/maintain–improve) [12] indicates as the first priority the avoidance of (or reduction in) energy consumption (by implementing optimised solutions, and also by supporting a responsible behaviour of the final users), followed by shifting towards more sustainable energy sources and improving the efficiency of these technologies.

The importance of defining new socio-economic and behavioural models is recognised in the literature as a key element to trigger change and build new models of energy production and consumption that are sustainable and durable. The adoption of participatory models and distributed systems within free markets can lead to the adoption of principles of ED and a sharing economy that can support the energy transition process and, at the same time, reduce the phenomenon of energy poverty, the situation in which households are unable to access essential energy services and products [13]. Models of aggregation of energy production and consumption have developed in different contexts and for different purposes. A growing interest in academia, policy and practice is being devoted precisely to the role of social innovation in addressing the energy and environmental conditions of today's society [14–18]. Social innovation is understood as the design and implementation of new solutions involving conceptual, process, product or organisational changes to improve the wellbeing of individuals and communities. In this context, collective self-production and self-consumption initiatives, local networks and energy communities represent social innovations that enable the collective adoption and implementation of new knowledge, generating new social and economic relationships to address socio-economic and environmental problems [19–22].

The transformation towards sustainability requires changes in the norms, values and behaviour that go beyond what the market and the state alone can achieve. In this context, it becomes clear that global decarbonisation goals can be achieved by creating new types of 'social contracts' between governments and an active civil society.

In the new concept of energy citizenship envisioned by the European Commission, citizens are no longer only passive consumers but they can become aware and informed users who actively participate in energy systems, generating a positive impact for the decarbonisation of energy systems. Furthermore, the involvement of the citizens, and therefore of the local community, can support an increased level of ED, thanks to the decentralisation of energy production plants and collective initiatives and ownership.

The model of the energy community (EC) is emerging, in which consumers and prosumers coordinate themselves to optimize the production and consumption of energy at the local level. ECs are a phenomenon of a differing nature in liberalised energy systems. In general, they consist of a heterogeneous set of collective actors performing one or more functions in the energy sector.

The model of EC is gaining interest in different countries, especially in Europe. With the reform of the legal framework governing the European Union energy sector in 2018 and 2019 within the "Clean Energy for All Europeans Package" [4], the EU acknowledges the need to empower energy consumers and, for the first time, addresses "citizens" in particular to accelerate the transition toward a low-carbon energy sector.

Accordingly, new actors and specific definitions are introduced:

- Renewable self-consumers, article 21 of the Renewable Energy Directive recast (RED II) of December 2018 [23] (as part of its Fit for 55 Package, the European Commission proposed a further revision of the RED II and of the revised electricity directive, that did not affect energy communities [23,24]);
- Renewable energy communities (RECs), articles 2 and 22 of the REDII [23];

- Citizen energy communities (CECs), article 2.11 of the Revised Electricity Directive (IEMD) of June 2019 [25].

A number of EU initiatives are supporting activities on ECs, collective forms of self-production and -consumption and distributed energy systems. Among them, funding from research programs (e.g., Horizon and Interreg), the Energy Communities Repository [26], the Rural Energy Communities Advisory Hub [27] is included.

Energy communities are broadly defined as "Citizen-driven energy actions that contribute to the clean energy transition, advancing energy efficiency within local communities" [28]. Some common key elements characterize Renewable and Citizens ECs in terms of activities and purpose, yet differences exist. The three major differences are the following:

1. The type of controlling EC member (this role can be only held by a natural person for a CEC, while for an REC, it is extended also to public administrations or small- and medium-sized companies).
2. The geographical location (necessary condition of geographical proximity for a REC).
3. Use of renewable energy: mandatory for REC.

Under EU legislation, the main purpose of both Renewable and Citizens ECs is "to provide environmental, economic, or social community benefits for its shareholders or members or for the local areas where it operates, rather than financial profits" (Article 2.16 in [23] and Article 2.11 in [25]). All final customers, in particular, household customers, are entitled to participate in renewable ECs provided that their participation does not constitute their primary commercial or professional activity. Membership of citizen ECs is also open to all categories of entities, whereas the decision-making powers are limited to members or shareholders that are not engaged in large-scale commercial activity and for which the energy sector does not constitute a primary area of economic activity.

Both CECs and RECs stem from a long European tradition of local cooperation on energy needs and the use of renewable energy. A large variety of ECs already existed in EU member states prior to the adoption of the directives that established them in the EU regulation. Therefore, the experiences of energy communities that do not comply with EU directives will also be included in the discussion if relevant for the analysis.

In recent years, an increasing number of studies have analysed energy communities in order to investigate several elements. Among the main ones are the policy and regulatory framework and its evolution; economic and environmental benefits; technologies; successful start-up and management; motivation of individuals to participate; social role; community design; business models; main barriers and shortcomings; and case studies and implementation. Accurate and up-to-date statistics on energy communities are difficult to find and often not easily comparable between countries. The total number of cooperatives across Europe is not officially recorded, but it should be higher than 3000, comparing available sources. REScoop.eu gathers around 1900 renewable energy cooperatives with approximately 1.25 million individual members [29], although the same source estimates that these are only half of the active renewable energy cooperatives in Europe. Other sources report that more than 3500 cooperatives have been founded across Europe [30] as of 2020.

Three main strands can be identified in the literature on ECs: broad analyses that aim to provide an overview of the phenomenon and its characteristics; sectoral analyses aimed at investigating specific aspects/topics; and analyses of case studies and implemented energy communities. Alongside studies aimed at overcoming regulatory and economic barriers, some scholars question the widespread narrative of ECs being inherently beneficial [31,32]. They highlight the need to assess the actual impact of ECs in terms of EJ, ED, community empowerment and social capital through quantitative and experimental studies.

In this paper, we summarize the existing literature focusing on ECs in the European Union to evaluate the dimensions and aspects that should be considered when assessing positive and negative impacts. The main findings from the literature are analysed in order to identify the conditions necessary for ECs to bring about social, environmental and economic improvements. An EC framework is proposed, and the enabling elements, business model dimensions and facilitating factors are identified and discussed in order to provide an overview of the main policy and research needs supporting ECs in delivering positive impacts.

2. A Framework for Energy Communities

This article discusses the experiences of organisational forms generally referred to as "energy communities" carried out in EU countries, including the ones enshrined in EU legislation [23,25], known as RECs and CECs. Since the process of transposing EU directives and adopting appropriate laws and regulations in the various countries of the European community is still ongoing, also the experience from types of energy communities that do not fully meet the requirements of the directives is examined, analysing the critical issues and benefits encountered to draw useful lessons for the implementation of RECs and CECs.

According to the EU definition, and also to its broad definition, the main purpose of an EC is to provide environmental, economic and social benefits to its shareholders/members and, consequently, also to the communities and local areas in which it operates. As extensively discussed in the literature (among them being [33–36]), energy communities are expected to enhance citizen participation in energy topics, increase the acceptance of the transition to renewable energy, and have social, economic and environmental benefits at the community and individual levels. These include strengthening EJ, the inclusion of energy savings in the cost of energy or other services or revenues, the creation of local jobs, a reduction in pollutant and/or harmful emissions, the use of local resources, and so on. EJ is often defined as an energy system that equally spreads both the benefits and costs of energy services, with representative and impartial decision making on energy issues [6]. ED and EJ are often used synonymously, implicitly assuming that democratised energy systems lead to improving EJ and the inclusivity of different social segments. A discussion of the differences and interconnections between ED, EJ and inclusion goes beyond the scope of the present work, so we refer to [8,37,38] and to the wide literature available for further analysis.

ECs are also expected to lead to a greater acceptance of renewable energy throughout society and a change in social norms towards energy, an increase in social cohesion, social capital and community empowerment.

The elements of the three dimensions of sustainability most relevant for ECs are listed in Table 1, with durability and replicability being additional relevant elements in the context of initiatives for the energy transition. It is important to remark that these impact categories do not represent the a priori benefits of ECs, as each of them must be carefully analysed for any specific EC. The actual positive or negative impacts depend on the characteristics of the context and the choices and strategies behind the implementation and organisation of an EC.

Table 1. Main impact categories of energy communities (authors' elaboration based on [39,40]).

Social	Environmental	Economic
energy justice	resource consumption	reduced costs
energy democracy	GHGs emissions	local jobs
community and empowerment	pollutant/harmful emissions and impacts	revenues
social capital	local RES	opportunities for companies
social cohesion	resource efficiency	affordable energy costs
social wellbeing	responsible use of resources	invest in local generation
health and safety	environmental wellbeing	cost- effectiveness

The main research question posed in this paper can be summarised as follows:

Under what conditions can energy communities bring improvement in the three dimensions of sustainability (social, environmental and economic), according to the current EU climate strategy?

The research question can be further detailed in order to distinguish between the elements that can enable, constitute or facilitate ECs.

Enabling elements, as the word itself indicates, are those that, to varying degrees, enable the creation of collective energy initiatives and ECs. Without them, it would not be possible to initiate ECs capable of achieving positive outcomes. They are elements on which the stakeholders directly involved in the initiatives do not have the capacity (in terms of power and/or authority) to intervene, and they are described in Section 3. Conceptually, they are placed at the lower level of a hierarchical structure, culminating in the impacts of initiatives (Figure 1). They include, for example, the regulatory framework.

Constitutive or functional elements are those elements that are decided upon by the stakeholders directly involved in the initiatives. These elements represent the "building blocks" of initiatives and constitute the dimensions of the business model, which may take different configurations, depending on the specific context. These include, for example, the community value proposition and the community members.

Favourable factors, finally, are those that can stimulate and trigger the creation of an initiative. They are typically contextual and exogenous elements.

The research question can therefore be reformulated as follows:

What are the enabling elements, business model dimensions, and facilitating factors of EC models that can bring improvements in the three dimensions of sustainability?

The methodology adopted includes the following main steps:

- *Identification of the enabling elements* through the analysis of the academic, research and educational literature (Section 3);
- *Identification of the elements that constitute the business model* through analysis of the academic, research and educational literature (Section 4);
- *Analysis of case studies and experiences* from interviews with representatives of a number of ECs and the analysis of experiences from existing ECs (Sections 5 and 6);
- *Discussion of the comprehensive model* to study ECs and collective and citizen-driven energy actions. Graphical representation and discussion of the elements identified in the previous steps (Section 7).

In the final part of the document, we discuss the results of the analyses and the lessons learnt (Section 7). We offer some insights and recommendations for the creation of robust frameworks and models to support the development of durable initiatives capable of delivering the expected social, environmental and economic benefits and for further investigation.

The literature on forms of self-production and collective consumption of energy and ECs is very wide and has seen great expansion in recent years. Our review is designed to be exploratory rather than exhaustive, aiming at identifying key and emerging issues that need to be properly addressed for the sustainability of models and initiatives.

The geographical scope of investigation is the European Union, with a focus on France, Germany and Italy [41]. The countries studied were chosen as representative of situations with different characteristics and approaches to energy (such as energy mix, sectors, governance, culture and habits, and social structure). The focus interviews with the energy communities selected as case studies, presented in Section 6, were conducted done in January and February 2023.

The review was carried out on academic and research documents and on dissemination resources (approximately 120 documents, including articles from scientific journals, books and book chapters, technical papers and research project reports, and 40 dissemination resources, including websites, conference presentations, and articles from trade journals were analysed) with reference to the levels defined in Figure 1.

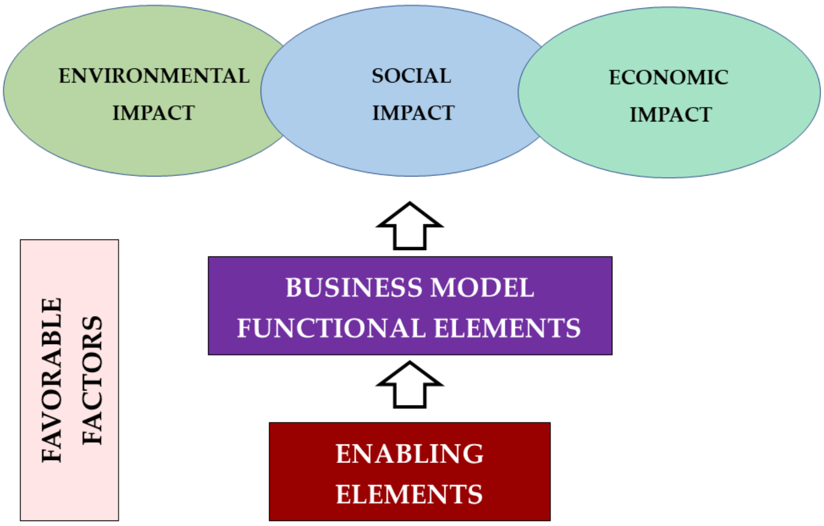

Figure 1. Graphical representation of the study model of energy communities.

3. Enabling Elements

In defining a simplified EC model to analyse the phenomenon and identify issues that require special attention or further analysis and research, we distinguished three main levels: enabling, functional and impact. The enabling level includes those elements considered necessary, though not sufficient, to achieve the functionality of ECs and thus be able to generate possible environmental, social and economic benefits.

We therefore identified the following elements as enablers for ECs. They will be discussed in the following subsections.

1. Legislative and regulatory frameworks;
2. Technology;
3. Social innovation framework.

3.1. Legislative and Administrative Frameworks

ECs have a long tradition in member states, such as Denmark and Germany [42]. Furthermore, before the European Directives, some national governments, like Austria, Germany, the UK, and Denmark, had already included RECs in their regulatory framework, mostly in an energy-cooperative form [43]. Instead, they play a minor role in Eastern European countries.

The EU legal framework obliges the member states to develop a "facilitating legal framework for energy communities". Yet, the directives leave a considerable level of discretion to the member states concerning the exact implementation and definition of the legal form, and the roles for ECs. The definition of the legal framework is a determining factor. If properly created, it can steer and support the development of ECs. If inadequately defined, on the contrary, it can hinder, block or even stop it [44]. Now that the framework for promoting ECs has been set up at EU level, it is important to verify how this framework is implemented by countries and subnational policy levels to ensure energy and territorial justice. National lawmakers have to revise their legal frameworks to ensure that the requirements of the directives are met and that the further development of ECs is explicitly facilitated and promoted.

The RED II and IEMD directives require that the CECs and RECs assume legal forms but without giving indications and delegating the matter to the individual states, with respect to the principles of open and voluntary participation and non-profitability. Therefore, a wide range of possibilities for the choice of legal form is allowed, such as cooperatives, limited partnerships, foundations and other socially oriented enterprises [45]. The legal form of the cooperative, as it allows for centralised ownership, is the most widespread in Europe and in line with the preferably centralised management of the energy markets in

European countries. In fact, as of 2020, more than 3500 cooperatives had been founded across Europe [30].

As far as the Italian case is concerned, the choice of the legal form is dictated by the compromise between costs and streamlining of the procedure, and legal robustness. For instance, the cooperative is a complex and expensive structure, (e.g., for the stipulation of a statute and for registration by notary), but guarantees legal protection in the event of disputes and damages caused by energy production plants. Instead, the association form provides for a simpler and cheaper constitution but has a more fragile structure. Furthermore, the Italian Court of Auditors expressed a non-binding negative opinion regarding the choice of a limited liability consortium legal form when the EC includes a public administration [46].

Finally, the full transposition of EU directives and the adoption of appropriate laws and regulations in the various countries of the European community is ongoing, and a unified approach to the development of ECs is still missing. Some issues remain to be solved, including the regulatory and administrative aspects, the need for the non-discriminatory treatment of RECs and CECs and to facilitate relations between DSOs and ECs, the costs, the contribution to the overall cost sharing of the systems, and the direct public participation in ECs. Moreover, the possibility for citizens to distribute the self-produced energy to other citizens without a professional retailer is still not widely available.

The implementation of RECs and CECs largely depends also on the administrative infrastructure available in single EU countries that are characterised by a high degree of heterogeneity. It is affected to a great extent by the rate of bureaucracy, the procedures for establishing the EC, the financial management capacity and the level of experience in new energy matters of the structures involved. For instance, in Germany and Italy, the administrative bottlenecks in planning and authorisation processes represent a significant barrier for the widespread implementation of ECs compliant with EU Directives [47].

In general, the widespread development of ECs requires structural adjustments of the governance system, and in most cases the legal barriers encountered are mentioned as one of the main obstacles for the decentralisation of energy models as witnessed in several works [47–50].

3.2. Technologies

The implementation of ECs is allowed by a number of technologies that have been improved over the years, both for electricity generation and for power consumption monitoring and management.

The main goal of ECs, when considering energy consumption and environmental impact optimisation, is to maximize the self-consumption of locally produced renewable energy, usually from PV systems [51]. Although PV is the main energy source in RECs, thanks to its global availability, other examples include mountain areas that exploit the available hydropower [52] or cases that include bioenergy and wind energy [53].

Shram et al. [54] compare the potential effect of different technologies in eight European countries, highlighting the importance of sharing energy at the local level to optimize the benefits of each technology. Better results are achieved in Southern Europe, thanks to the higher annual irradiation supporting better PV productivity, and the higher average emission factor of the electricity supplied by the power network.

Electricity production technologies also benefit from integration with other solutions to maximize the share of self-consumption, including demand-side management strategies [55] and behind-the-meter electricity storage [56]. The suitability of these options should be evaluated by comparing the actual or expected electricity demand load with the available local generation, to account for potential mismatches that can benefit load shift or electricity storage. At the same time, the additional flexibility provided by these technologies should be accounted for when evaluating the opportunity of incurring additional costs for their installation.

While ECs are mostly limited to electricity networks, it is also important to remember that in some cases, they are also potentially integrating heat networks [57,58]. Although with some technical differences and limitations, most of the aspects that are discussed in this work are also potentially relevant for thermal energy communities. Heat networks have seen, in some cases, the integration of local generation, but the management of flows and temperatures with multiple prosumers is generally more complicated compared to electricity networks. Moreover, thermal energy communities are different regarding the distribution and storage infrastructure, the investment costs, the size and features of the generators, and the demand patterns and behaviours of the consumers [59]. Nevertheless, most of the enabling elements and functional elements that we discuss in this work can be also extended to thermal energy communities.

An important aspect that needs to be considered for the success of EC models is their operation, including the monitoring of electricity generation and consumption of the different users that are involved. Although the existing technology often allows for the easy and relatively cheap real-time measurement of electricity, developing an effective and coherent monitoring system often requires additional costs that may not properly be anticipated in the EC business plan. Moreover, the integration of any new user in the EC would require that it also complies to the same system.

The availability of real-time operation data is paramount to ensure the effectiveness of ECs, both in environmental and economic sustainability. Pasqui et al. [60] highlight how an optimal operation of available batteries supported by monitoring data can ensure the best operation of an EC to maximize the collective self-consumption of available renewable energy. The real-time monitoring and operation can also be coupled to advanced technologies and tools to optimize the benefits of the EC and the services that can be provided to the grid. Hernandez-Matheus et al. [61] discuss the potential contribution of machine learning techniques to support the operation of ECs, by comparing different algorithms and solutions: while supervised learning can provide accurate models for forecasting tasks, reinforcement learning presents interesting capabilities in terms of control-related applications. The authors also highlight a gap in the literature about how the uncertainty of users' behaviour is integrated into control algorithms, energy management systems, and forecasting methods. The operation of ECs will also involve solutions to certify the exchange of energy between producers and consumers, such as tokenisation and smart contracts [62].

A final aspect to be considered is the aggregation of monitoring data from different ECs in a centralised database. The availability of a large dataset from real cases can provide an important resource to support the analysis of the actual performance of different ECs, helping the development of advanced optimisation tools. At the same time, the implementation and maintenance of such a system would lead to additional costs and challenges, especially if data are to be collected in real time. The development of a centralised dataset, such as at the national level, would also need a clear set of standards to ensure that the monitoring systems of the different ECs can provide the required data in a coherent and complete process.

3.3. Social Innovation Frameworks

In addition to the legal and legislative aspects and the adoption of technologies with lower environmental impact and greater efficiency, the process of transforming society towards environmental and social sustainability requires interdependent changes in values, norms and behaviour by multiple actors. The production and consumption patterns of all actors in the system, including individuals (consumers and citizens/families in a broad sense), must be changed. The transition to sustainable energy systems, adopting zero-carbon technologies and an efficient and conscious use of energy, is an area that shows interconnections between technical/technological innovations and social innovations. Scholars raise the question of how to support such an important transformation, given these complex interconnections and the evidence that society and policy are acting so slowly that climate risks seem to be increasing rapidly [63].

It is increasingly recognised that the social aspect is an essential, often overlooked, component of the energy transition [15]. Research has traditionally focused on market and technology-based changes, while the social aspect has traditionally been framed in terms of "social acceptance" [64]. More recently, some authors have brought to attention co-evolutionary innovation studies and "sustainability transitions" [16–18], leading to a more articulated understanding of the dynamics between local communities and energy transition [65]. In order to change the consumption and production patterns that are unsustainable in the socio-technical systems related to energy (sectors of electricity and heat production, buildings and mobility), incremental improvements and technological solutions are not enough [66]. Radical changes are needed towards new types of socio-technical systems, changes that are called 'transitions of sustainability' [18,67].

Some authors focus on the analysis of processes that lead to radical changes in the way social functions are fulfilled on a "meso" level of socio-technical systems [68], that of communities and groups of people. Specifically, Köhler et al. [66] identify the following characteristics of sustainability transitions: multi-dimensionality and co-evolution; multi-actor process; stability and change; long-term process; open-endedness and uncertainties; values, contestation and disagreement; and normative directionality.

Hanish and Fairbairn [69] point out the important role of cognitive aspects and social innovation processes and of their interaction with strictly technological aspects in the development processes of renewable energy and energy cooperatives and in the context of citizen co-construction and co-production of institutional policy.

4. Business Model Functional Elements

A business model (BM) is a widely accepted concept used by researchers to analyse how an organisation, be it a multinational company or a new venture, works and what it does to generate and capture value [70,71]. However, there are many views on how to describe and define the concept of a BM [71,72]. Here, we mainly refer to the definition given by [70], according to which the purpose of a BM is to identify how a company can create, capture and increase value through the development of competitive strategies. Several studies have recently approached energy BMs, as an adaptation of classical BMs, from different perspectives. However, the study of energy community business models (ECBMs) is still in the early stages of development, and a comprehensive picture of existing and emerging ECBMs is lacking in the literature [73]. This does not mean that a 'new' BM definition for ECs is needed but that new approaches need to be developed that focus on social benefits rather than prioritizing profit [73,74].

It is also necessary to consider the context in which the firm operates and co-evolves with other elements of socio-technical systems, including external institutional, legal, financial and social constraints [75–77]. The BM architecture must therefore respect external barriers arising from available technologies, regulatory and market frameworks, and technical standards adopted for distribution networks. For all these reasons, the EC is usually said to act from an 'external perspective' with the aim of creating a sustainable model [74].

From the literature analysis, we identified key dimensions of ECBMs, discussed in Section 4.1, and main ECBM typologies, illustrated in Section 4.2.

4.1. Key Dimensions of Energy Community Business Models

The community value proposition corresponds to the value proposition in the BM canvas, declined as the value logic of sustainability. At least in the initial conception phase, it corresponds to the motivation of the proposers. The community value proposition must then be defined, as the name suggests, at the community level, involving multiple stakeholders. The social, environmental and economic value created must be redistributed among the stakeholders, while for the organisation, only the amount needed to reach/maintain the optimal scale must be captured [78].

Several authors have analysed and classified the value propositions of ECs, peer-to-peer and other non-purely commercial initiatives involving communities [39,78–80]. Value propositions can have different levels of economic focus and community orientation, the latter intended as community spirit, social goals and environmental benefits (also in ethical and cultural terms).

Energy community members correspond to the customer segments of Canvas, i.e., the groups of individuals or organisations to whom you want to provide value. Members of the EC can have different roles, the main ones being grouped as [80] actors who own assets and are connected to the network; facilitators who can act either as platform providers for direct business transactions between actors, or as intermediaries for actors to enable interactions with a broader market; and actors who act as service providers and potential customers of actors who own assets.

The main categories of community members are indicated in Table 2. Depending on the EC configuration, they may also be key partners, i.e., actors who make the EC work through co-operative agreements.

Table 2. Main categories of community members (authors' elaboration based on [74,80]).

Energy Community Members					
ECM01	residential prosumers	ECM06	(community) platform operators	ECM10	retailers
ECM02	other prosumers	ECM07	energy service companies	ECM11	network operators
ECM03	pure consumers	ECM08	aggregators		
ECM04	local energy producers	ECM09	representatives *		
ECM05	storage operators				

* Representatives are virtual entities, not physically connected to the network, acting on behalf of a single entity connected to the network. They manage the combination of their clients' individual assets to a potential plurality of trading agents or market platforms [80].

Key functions define a number of characteristics and tasks that are fundamental to the functioning of the EC. In the ECBM, key functions group the dimensions that in the Canvas model are referred to as channels, customer relationships, key resources, key activities and key partnerships [74,81,82]. Following the structure proposed by Kubli and Puranik [74], the main key function categories can be grouped into (Table 3) P2P trading (trade of energy and/or flexibility through a market platform, market operation); aggregating energy and flexibility (central coordination and bundling of energy services to a larger pool, services to the grid); managing storage systems (operation and optimisation of all kinds of storage services, based on batteries or on vector conversion technologies); co-optimising energies (optimisation of demand and generation characteristics through local energy management services, resource management); and coordinating partners (engagement of external partners).

Key functions include a large number of elements, and other categorisation logics are possible, depending on the level of detail and the number of elements that need to be reached. We believe that this choice [74] represents a good balance and representation of the main aspects that are of interest.

Table 3. Key function elements (authors' elaboration based on [74]).

Key Functions			
KF01	P2P and electricity trading	KF04	co-optimising energies
KF02	aggregating energy and flexibility	KF05	coordinating partners
KF03	managing storage systems		

The energy value capture block corresponds to Canvas' revenue streams and cost structure. It includes the various cost items, both fixed and variable, and revenues, both based on static and dynamic variables. The main energy value capture elements are listed in Table 4, without being distinguished according to key customer segments and other BM elements.

Here, we focus on the revenues side, i.e., on the income obtained from the value proposition(s) provided to customers. Following the structure proposed by Kubli and Puranik [74], the main revenue categories consist of energy services (e.g., sale of mobility, heating, electricity and/or energy management services to community members); energy cost savings (cost reduction, e.g., through smart energy management, energy efficiency, self-consumption, peak consumption reduction, and shifting of demand to low-tariff schedules); external services (e.g., provision of balancing energy, capacity through smart energy management, energy efficiency, self-consumption, reducing peak consumption, and shifting demand to low-tariff schedules); community investment (financial involvement of community members through shares, memberships, taxes or tariffs); and data valorisation (production and consumption data, operation, habits and behaviour, etc.).

Although many studies focus on the reduction in investment and operational costs, it is important to consider how different BMs may provide different allocations of economic benefits to end users. In this regard, Casalicchio et al. [33] propose a methodology to assess the fair allocation of benefits within the community by BMs.

Table 4. Energy value capture elements (authors' elaboration based on [74]).

Energy Value Capture			
Revenues		**Costs**	
VCR01	revenues from energy services	VCC01	installation
VCR02	saving energy costs	VCC02	maintenance
VCR03	revenues from external services	VCC03	energy consumption
VCR04	community investing	VCC04	management
VCR05	data valorisation		

The network effect refers to the concept that the value created by offering a product or service increases when the number of people using it increases. Network effects, both direct and indirect, are key elements for energy communities to reach their full operational capacity and develop successfully.

4.2. Business Model Typologies for Energy Communities

The lack of a systematic approach to developing the classification of BMs that uniquely determines which criteria to use or for what purpose the classification may be useful makes the subject complex and can create misunderstandings and confusion [83]. This is also true for ECBMs, for which different classification schemes are reported in the literature, depending on which variables are considered useful for classification.

Kubli et al. classify ECBMs [74] on the basis of the key dimension discussed in Section 4.1. It is possible to have other types of classifications, defined on the basis of the different types of governance and legal structures, investment, asset ownership, and services provided.

Regarding the legal structures, ECBMs can be classified as [33,84] limited partnerships, in which governance depends on the invested share of each partner; community trusts and foundations, whose aim is to generate profits to invest in social projects to support local development; non-profit customer-owned enterprises, which are a typical structure of EC developed in rural areas to deal with the management of independent grid networks; public–private partnerships, in which local authorities establish a partnership with private organisations or citizen groups to create a business able to create benefits for a community; and public utility companies that are managed by municipalities on behalf of citizens.

In terms of investment options [85], ECs can be classified into two main categories: third-party investment (where a third party can invest in DERs); and self-investment (where consumers themselves can invest in DERs). For both investment options, investors take ownership of the community energy system and bear the costs and risks. The distribution of costs among community members is a relevant issue to be addressed, which has to take into account more than just the costs of electricity supply among end users according to the electricity price [82].

From the analysis of existing EC configurations reported in the literature, Reis et al. identified eight ECBM archetypes [82]: energy cooperatives, community prosumerism, local energy markets, community collective generation, third-party sponsored communities, community flexibility aggregation, community energy service companies, and e-mobility cooperatives.

Starting from the classification proposed by Reis et al., we adopt a classification consisting of the following five categories of ECBMs, illustrated in the following sections:

1. Energy cooperatives;
2. Community prosumerism;
3. Community collective generation;
4. Third-party-sponsored communities;
5. Community flexibility aggregation.

In our approach, local energy market (LEM) communities are considered a particular example of prosumer communities, energy service companies (ESCO) communities are included in third-party sponsored communities, and e-mobility cooperatives are among the flexibility aggregation communities.

Energy cooperatives are the most commonly used scheme in the EU. Several cases have been developed in Denmark, Germany, France and Spain, even before the regulatory framework was as clear and detailed as it is today. The energy cooperative scheme was born with the aim of increasing the involvement of the final consumer: it is the typical scheme based on citizen-led initiatives with voluntary participation, where all members play a role and control is decentralised [74]. Energy cooperatives can be for profit or non-profit. In the first case, revenues (e.g., from the sale of energy) are the lever that drives the stakeholders to join the community; in the second case, the need to improve the local context in which the community operates, or the desire to increase the amount of energy from renewable sources, is the purpose for which the different stakeholders collaborate. This scheme also guarantees two-way benefits for co-operatives and municipalities: the former can obtain technical and financial support during the development process, while the latter can obtain a reduction in energy costs or take advantage of other services provided by the energy co-operative [74].

Community prosumerism is the scheme characterised by the presence of a central decision maker who acts for the welfare of all members belonging to the EC. The central decision maker knows the variables of the system and manages loads and energy production to ensure that the optimal economic target is reached. Potential revenues from the sale of excess energy can be distributed among prosumers to repay their investments or reinvest in the community to improve the social infrastructure and expand installed generation or storage capacities. The relationships between the different actors are regulated by PPA contracts that also establish the remuneration mechanisms between the various partners.

A particular configuration developed by the prosumerism-oriented model is the LEM community [80]. The objective of this model is to maximise profits for EC members by considering the participation of EC members in the internal or local energy market [82]. In fact, unlike in the energy market, where traded energy (bought or sold) is remunerated at the market price derived from national trading, if there is a local market, the retail price can be negotiated directly between market participants [82]. The revenues obtained are shared between the different actors involved in the EC and the consumers. The distribution system operator (DSO) ensures the reliability of the supply and trading system [82]. However, although the literature acknowledges that the LEM is an important tool for the development of the EC, it is limited by the need to protect data sharing between all actors in the system. To overcome the aforementioned problem, new systems and technologies are the subject of recent studies [82]. One of the main solutions is the blockchain, which, thanks to a particular algorithm, avoids the need for a trust authority and the accessibility of the information to EC participants [82].

Collective self-consumption BMs, often referred to as community collective generation, are based on shared energy generation (usually solar PV) and possibly storage systems. PV systems are installed on the rooftop of multi-tenancy buildings or in the vicinity of consumption sites, with the power output being shared among several customers. Due to their characteristics, these BMs are constituted as communities of place. Typically, the investment is shared by the dwelling owners (consumers, decision makers and investors), and sophisticated net metering and ICT-based infrastructures are required [82]. Also, the distribution of the self-generated energy and potential revenues from the sale of surpluses depends on specific rules that are established voluntarily and collaboratively among all project participants [82]. These BMs are emerging across Europe.

In the configuration called third-party-sponsored community, the decision makers (investors) maximize own revenues providing energy supply solutions based on the real needs of community participants. So, the investors cooperate closely with local communities, sometimes involving community representatives in the decision-making processes. A particular shape of the third-party scheme is represented by Community ESCO, in which the third party is an energy service company that provide free energy services (i.e., the installation of PV panels, or boiler, . . .) to obtain extra energy savings. The extra energy savings represents the only remuneration for the ESCO. Sometimes, the third-party scheme can have also no profit scope: in this case, third parties finance by crowdfunding or other investment funds the EC constitution with a social purpose, and all obtained revenues are re-invested in the EC for the local economic development.

The community flexibility aggregation BM scheme is addressed to all final customers able to reduce their own energy consumption in exchange for an economic benefit, i.e., a reduction in energy price or other economic incentives. This is the logic at the basis of the DSM or DR programs, particularly used in the past by the distribution system operator (DSO) to manage loads that are so-called "controllable". Today, thanks to the new energy structures, such as EC, but also micro and smart grids (SG), this possibility is given to residential consumers. Obviously, an aggregator must manage loads provided by all participants in the programme to achieve the volumes required to make offers in balancing, reserve and ancillary markets, thus enabling the participation of small end users in such markets [82]. Bilateral contracts are signed between community aggregators and customers through which customers commit to deliver fixed amounts of flexibility by changing energy consumption patterns and benefiting from reduced energy bills. Penalties can be charged if the promised amounts are not delivered, strengthening the commitment on the customer side [82,86]. Regulatory frameworks play a key role in the deployment of these BM, as they can constrain the aggregators' scope of action. A particular shape of community flexibility aggregation is represented by the electric mobility cooperative. These cooperatives can also exploit their assets (electric cars, buses, motorbikes, etc.) as flexibility resources [82,87,88]. Batteries can be used as storage resources, exploiting vehicle-to-grid and grid-to-vehicle modes to reduce energy bills by procuring energy during off-peak periods and providing flexibility services, which can be pooled by aggregators to deliver ancillary services to the grid [82,88]. Additionally, if these cooperatives are also involved in power generation, battery storage helps to maximize local self-consumption and self-sufficiency. In these BMs, community participants may be involved (through partnerships or not) as shareholders, decision makers and mobility customers. In ECs with high shares of EVs (communities of place), smart charging schemes can be designed to schedule load operation to off-peak periods or when local energy generation is available, thus optimising the utilisation of local resources and flattening demand peaks [82,88].

5. Impacts

5.1. Social Impact

The social role of ECs outlined in EU legislation [23] is explicitly aimed at energy poverty alleviation and the participation of all social groups in ECs, particularly those groups that are underrepresented among REC members. However, ECs that actively contribute to energy justice by engaging with vulnerable and underrepresented groups and providing access to their services to alleviate energy poverty remain an exception [89].

In the social field, as well as the need to expand the body of research on social innovation processes, there is also the call to define robust and shared methodologies for measuring social impact. Some scholars point out that EC research has focused mainly on how to successfully launch and manage ECs and on their benefits in terms of environmental or economic impact, while the potential social benefits seem to be underestimated or not adequately investigated [31,90,91]. It concerns direct or indirect change in individuals or in a community (from a perceptive or physical perspective) associated with the creation of social value. The definition of social impact focuses on both the individual and the community levels and goes beyond purely economic benefits for communities. In Bielig et al. [31], a literature review is conducted on the social impact of ECs in Europe, understood in terms of energy justice, energy democracy, community empowerment and social capital. The authors indicate that the evidence of the social impact of ECs is still fragmented and that the literature is insufficient in terms of methodology and geographical scope. Among the main gaps, they identify the lack of quantitative evidence and of evidence from countries from Eastern and Southern Europe. As research recommendations, scholars recommend future research to focus more on rigorous quantitative testing and more robust methodologies [31,92]. This includes surveying larger sample sizes, with greater inclusiveness and diversity, and promoting mixed-method approaches so that causal inferences can be determined and EC models can be identified that have a greater social impact. At the policy level, the need to evaluate and promote ECs also according to their social impact objectives, not only economic and environmental ones, is highlighted. The need to strengthen the principles of diversity and inclusion of marginalised groups and vulnerable families in participation and empowerment in order to strengthen the social role of the EC in the energy transition, is also pointed out [89]. Social impacts may also include additional benefits that are very site-specific. Stroink et al. [93] describe the opportunity of developing cross-border ECs across countries in the EU as a way to strengthen structurally weak border regions.

5.2. Environmental Impact

ECs have been widely analysed in the literature to assess their potential of energy and emission savings.

High levels of self-consumption can be reached when the EC is composed by users that have different demand patterns. This is often the case when residential buildings are coupled with offices or other commercial activities. Ceglia et al. [94] evaluate the benefits of an EC composed by different residential buildings and restaurants, considering the sharing of the electricity produced by PV systems installed on the roof of the users. Their results show a potential of 38% of CO_2 emission savings thanks to an annual self-consumption level of 56% of the total electricity generated by the PV systems.

In this perspective, the availability of flexible loads that can be operated with demand-side management is an important resource for an EC. A study by Casalicchio et al. [55] shows that the availability of a 20% flexible load and a heterogeneous composition of the users can allow for a reduction of 13% in PV and 93% in storage system capacity with respect to the case without DSM. The flexible load includes electricity uses that can be shifted over the day based on electricity prices or the availability of local renewable generation.

Cutore et al. [56] evaluate a specific case study in Italy, simulating the optimal operation of an EC with and without battery energy storage on site, reaching a maximum CO_2 emissions saving of 34% compared to the base case without the EC in place. The authors also propose an approach to tackle energy poverty, in which the economic revenues of the excess electricity sold to the market are redistributed to low-income families that are part of the community.

In some applications, the EC concept is extended beyond the electricity network to account for the potential integration of heat networks. Li et al. [57] analyse a peer-to-peer multi-energy sharing mechanism that is able to ensure up to 9% of carbon emission savings. Abdalla et al. [58] evaluate the potential benefits of connecting clusters of buildings nearby large sites with high year-round cooling and refrigeration demand (e.g., ice arenas and grocery stores) to exploit the waste heat as an input to other buildings' heating demand. An efficient operation of a shared heat network could allow for up to 74% of emission savings.

Some research works also highlight the importance of optimising both the design and the operational phases of the communities. The analysis of Dal Cin et al. [95] shows the importance of optimising both generation and storage units, together with demand-side management strategies to decrease energy consumption and costs. The case studies proposed by the authors reach a decrease of 14% of the energy costs and 24% of the CO_2 emissions when compared with a reference case of separated consumers.

5.3. Economic Impact

The economic benefits of ECs have been discussed extensively in the literature, although limited evidence from real cases is available. This is due to the difficulty of finding accurate information, also considering the fact that many ECs are currently still in the development phase. Depending on the configuration adopted and on the key customers, ECs can lead to economic benefits that include reduced energy costs, reduced grid tariffs, revenues from financial incentives, reduced other costs, and access to services and goods. The reduction in the cost of energy is due to the fact that self-generated renewable energy is cheaper than the retail tariff. While aggregation effects allow for lower grid tariffs [96,97], reductions in consumption also have a positive impact on decreasing transmission expansion and, consequently, on reducing the average cost of electricity in Europe [96,98]. Indirect economic benefits are due to the guarantee of a better security of local supply in the event of power supply disturbances elsewhere in the network [97,99], local job creation, increased expertise and other cascading effects.

The criteria used to distribute the gains between the partners are a key to success for the EC, and an important element of the BM [100]. The simplest way is to distribute earnings equally among all members [97] according to the energy produced or consumed. However, this strategy does not prove successful if the consumption profiles are too different. To overcome this problem, therefore, a centralised controller (or prosumer) is part of the EC to manage it optimally. Costs and profits can be shared according to the area of PV panels installed by each participant [101,102], while grid costs are distributed equally among the system users. The economics of energy sharing can change significantly depending on the specific decisions made by regulators (e.g., on the space and time interval in which CSC can be performed or on the grid charges and levies applied to shared energy) [100]. It is therefore critical for a community to agree on a sustainable way of sharing benefits and to attract a sufficient number of members with sufficiently diverse generation and load profiles [97,103]. Biggar and Hesamzadeh [32] analyse whether the creation of ECs can improve overall economic welfare. Their work shows that if retail tariffs are inefficiently structured, the creation of an EC can exacerbate existing problems in retail tariffs and potentially also undermine the ability of the local distribution network to efficiently price local congestion. The authors conclude that tariff reform should precede ECs.

A final element to be taken into account is the trade-off between economic and environmental benefits, both in the design and operation of ECs. Different analyses in the literature show that the best economic configuration is not always the one that ensures the lowest environmental impact as is often the case for a range of energy systems. Cirone et al. [104] show that when sizing PV and storage systems in an EC, the optimal emission savings and net present value may not correspond to the same system configuration, leading to the need to choose a specific priority when designing the system. Sudhoff et al. [105] compare different operation strategies in a specific EC, showing that an optimisation of the economic benefits of its members does not reduce the annual peak load, while a strategy focused on a grid-friendly renewable EC achieves a peak power reduction of 23–55%.

6. Case Studies

In this section, qualitative and quantitative information on real cases is collected in order to analyse how the key elements previously discussed have been addressed, to identify further key elements and to provide insights for further actions.

Five examples of ECs from three European countries (France, Germany, and Italy) were selected for interview. The five case studies were chosen for their characteristics, which make them useful for drawing conclusions to be included in the discussion because of their relevance at the local, national, and European levels. They were also selected because they were initiated prior to or contextually with the EU directives, so while they may be models that cannot be replicated, they are also able to provide useful cross-references on errors, potentials, needs and risks, and on the evolution of the sector as they are working on new initiatives. Indeed, the communities themselves and their key actors are involved in promoting local communities and are participating in national and European working tables and research projects.

The categories of the five main dimensions of the BM adopted in the case studies examined are shown in Figure 2. The choice of the appropriate indicators was made by the authors on the basis of the answers received by the representatives of the ECs and not directly asked to them. This choice was made to ensure better comparability across the case studies that are considered. The acronyms used refer to the categories in Tables 2–6.

	ACV	ECVMG	NEA	EnCityHall	EWH
Value Proposition	VP01, VP02, VP04, VP05, VP08, VP09, VP10, VP14, VP16, VP17	VP01, VP10, VP15, VP16	VP01, VP02, VP03, VP04, VP10, VP15, VP16	VP04, VP17	VP01, VP02, VP03, VP04, VP08, VP09, VP10, VP13, VP14
Energy Community Members	ECM01, ECM02, ECM03	ECM02	ECM01, ECM02, ECM03	ECM02, ECM03	ECM02, ECM03, ECM04, ECM06, ECM07, ECM10, ECM11
Energy Value Capture	VCR01, VCR02	VCR01, VCR02	VCR01, VCR02, VCR03	VCR02	VCR01, VCR02
Key Functions	KF01	KF01, KF05	KF01, KF02, KF05	KF01	KF01, KF02
Network Effects	NE01, NE02, NE03, NE04	NE02, NE03, NE04	NE02, NE03, NE04	NE01, NE03, NE04	NE01, NE02, NEO3, NEO4

Figure 2. Synthesis of the main BM elements in the case studies.

Table 5. Main categories of community value propositions (authors' elaboration based on [39,78–80]).

Value Proposition					
VP01	reduce costs	VP06	energy autarky *	VP12	social sustainability
VP02	get revenues	VP07	energy autonomy **	VP13	community welfare
VP03	enter LEM	VP08	desire for greater agency in the energy transition	VP14	sense of community identity and social relationships
VP04	energy from local RES	VP09	responsibility to future generations	VP15	regionality
VP05	reduce energy consumption	VP10	contribution to sustainable society	VP16	local retention of benefits
		VP11	inclusion	VP17	become a living lab

* Autarky refers to energy self-sufficiency through (total or partial) dependence on self-produced energy and limited interaction with the wider electricity system (including ensuring continuity of energy supply) [79,106]. ** Autonomy means independence from an energy supplier or co-determination in the EC. It is expressed through ownership, involvement in decision making or independence [79,106].

Table 6. Network effects (authors' elaboration based on [74]).

Network Effects			
NE01	peer effect and creating a community feeling	NE03	learning effects
NE02	economies of scale and scope	NE04	co-benefits and co-amortisation of investments

Figure 3 shows the occurrences of each category of the BM dimensions in the case studies analysed. The results do not pretend to have a quantitative validity, given the small number of case studies and the specific peculiarities of each of them, but rather present a qualitative evaluation of the most frequent indicators.

	Indicator number on each category																
Categories	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17
Value Proposition	4	3	2	4	1	0	0	2	2	4	0	0	1	2	2	3	2
Energy Community Members	2	5	4	1	0	1	1	0	0	1	1						
Energy Value Capture	4	5	1	0	0												
Key Functions	5	2	0	0	2												
Network Effects	3	4	4	4													

Figure 3. Occurrences of each category of the BM dimensions in the case studies analysed. The color scale is from red (low occurrence) to green (high occurrence).

The interviews explored aspects related to the inception and creation phase of the initiative, its operation and prospects for future development. The outline of the questions asked during the interviews can be found in Appendix A.

6.1. Association Centrales Villageoises—France

France represents an interesting study state. In fact, it appears to be the only country in the European Union that has not reached the targets for local renewable energy generation and is characterised by a highly centralised system for electricity production, also defined as a "nucleocracy", which has made citizens passive users [107]. Furthermore, energy communities need to attract members in a highly concentrated residential market and the economic leverage is limited since community members pay the same grid costs and taxes of ordinary citizens, and these amount to two-thirds of the final price [108].

Ahead of the times of the RED II directive, France had already adopted the Energy Transition Law for Green Growth in 2015 [109], which, in a pioneering way, facilitated juridical conditions for the inclusion of citizens in initiatives related to the production of renewable energy, also through dedicated incentives (called "participatory bonuses"). Subsequently. The RED II directive was transposed by article 40 of Law n. 2019-1147, and further decree n. 236/2021 introducing the definition of REC as defined at European level [84]. The French case differs from the Italian and German ones because a large contribution to the electricity mix derives mainly from the nuclear source, and secondarily hydroelectricity. Taking note of this contest, the role of REC in France has been defined as "important for its local contribution to social and economic solidarity". The number of RECs is growing very fast in the French framework, considering that its number quadrupled from 2014 to 2019 year, when 240 RECs were active in the whole country [110].

The Association Centrales Villageoises (ACV) [111] comprises 63 communities. Of them, 50 have already created a local company, in the form of a commercial or cooperative society, and 40 already have operational systems. The local companies are owned by shareholders, consisting of citizens, associations, municipalities and a small number of SMEs.

The main initiators of ACV is the so-called "Centrales Villageoises" network, including citizens and municipalities in the Auvergne-Rhône-Alpes Region. The association was created in 2018, building on the positive experience of the Centrales Villageoises (CV) network model. It was born in 2010 and originates from an experimental project initiated by the Auvergne-Rhône-Alpes Regional Energy Agency (AURA-EE) and five regional natural parks with the support of European and regional funds. From 2010 to 2014, it was tested in eight pilot sites and gradually led to the creation of local citizen-owned companies that designed and financed photovoltaic systems. The technical and legal model was then consolidated and allowed the concept to be replicated in other sites, spreading the CV model throughout the AURA region and in other regions.

The BM of ACV is that of the energy cooperative, which is moving towards the community collective generation. The main impacts of ACV are reported in Table 7.

Table 7. Main impacts of ACV.

Social	Environmental	Economic
community empowerment	resource consumption	local jobs
social cohesion	GHGs emissions	revenues
social wellbeing	local RES	invest in local generation
health and safety	responsible use of resources	affordable energy costs
energy democracy		

The two pillars of the initiative are the citizens and public institutions, mainly municipalities and regional nature parks. The determination of citizens to take concrete action to address climate and energy issues and to invest in initiatives with local benefits over which they can have some form of control, is the main motivation behind the creation of CVs and new ECs and collective initiatives. The new members who join EC projects, purchasing a share and volunteering their time, show interest in RES, participation in collective projects, social ties and economic benefits.

The development of new CV projects was facilitated by the availability of the replicable model created by AURA-EE and the Parks, which is functional regarding the need to develop RES projects that take into account local issues and citizens' expectations.

The evolution of the regulatory framework in France (e.g., new rules for incentives, regional tariffs and financing, definition of the distances at which energy can be sold) and the increase in costs are currently an obstacle for the start-up of new communities. For this reason, efforts are being made to develop new BMs that are more economically sustainable, with the installation of larger plants and increased individual and collective self-consumption.

6.2. Energy Communities in Piedmont Region—Italy

In Italy, after an experimental and transitory regulation in view of the complete transposition of Articles 21 and 22 of the RED II [23], the Italian legislative decree 199/2021 [112], which entered into force in December 2021, represents an acceleration of the country's sustainable growth path in line with the European objectives of decarbonisation of the energy system by 2030 and 2050. It overcomes the limitation implemented by the Legislative Decree 162/2019 (Article 42-bis) [113] that permits small-scale collective self-consumption characterised by renewable energy plants below 200 kW for renewable energy members connected to the same low-voltage distribution sub-grid. The main changes shaped by the Italian legislative decree 199/2021 about ECs concern the size of the plants (which is extended to 1 MW for each individual plant) and the possibility of having groups of self-consumers, consumers and producers connected to the same primary substation. Nevertheless, at the time of writing this article, the implementing decrees have not yet been published.

With the entry into force of the Regional Law 12/2018 [114], Piedmont is the first Italian region to promote the establishment of energy communities. Since December

2020, provisions and incentives have been in place to develop collective systems for self-consumption from renewable sources, which have led to successful experiments.

6.2.1. Valli Maira e Grana and Nuove Energie Alpine

The Comunità Energetica Valli Maira e Grana (CEVMG) comprises 21 municipalities. It was legally established in January 2021, in the form of a temporary purpose association.

The project was launched in 2018, by the initiative of the Maira and Grana Valley Mountain Unions. The main motivation for creating the EC was the need to manage local environmental and energy issues by improving the use of local resources (water and woody biomass) and supporting municipalities on energy issues. An additional element was the possibility of entrusting the management of compensations for large derivation concessions for hydroelectric production to a local authority and guaranteeing that the compensatory benefits would have repercussions for the communities (following art. 16 of the Piedmont Region Law No. 26/2020 [115]). The birth of CEVMG was facilitated by the entry into the force of the Regional Law 12/2018 in Piedmont [114] and by the granting of two economic contributions.A grant was awarded by the Piedmont Region (grant in favour of the establishment of energy communities in the framework of [114]), and another grant was awarded as first prize in the 'Piemonte Innovazione 2020' competition held by the National Association of Italian Municipalities, used to cover the start-up costs and equipment for the coordination office.

The free energy provision due, as compensation, from hydropower producers is used to power the public lighting systems of the EC member municipalities.

CEVMG has a BM of energy cooperatives, based on an approach of energy communities as "large area entities" operating on energy and environment. Among the objectives of CEVMG is the creation of a local energy market to become resellers and manage the supply of energy to member municipalities, through its membership in the newly established EC Nuove Energie Alpine (NEA). However, they are currently facing considerable obstacles due to legal and/or bureaucratic constraints in supplying energy to public entities. The main impacts of CEVMG are reported in Table 8.

Table 8. Main impacts of CEVMG.

Social	Environmental	Economic
community empowerment	resource consumption	reduced costs
social cohesion	GHGs emissions	local jobs
	local RES	revenues

NEA was established in December 2022 by six entirely public shareholders: CEVMG, the Azienda Cuneese dell'Acqua (a company owned by 108 municipalities that also deals with energy, as an ESCO) and four municipalities (Busca, Macra, Pradleves, Villar San Costanzo). The need to have a single aggregator that manages several ECs, thus distributing their management costs and avoiding the creation of multiple legal entities, was the primary motivation for setting up NEA. Its creation was favoured by the existence of CEVMG and by the availability of funding promoted by the Fondazione Cassa di Risparmio di Cuneo.

The BM of NEA is a third-parties-sponsored community. The main impacts of NEA are reported in Table 9.

Table 9. Main impacts of NEA.

Social	Environmental	Economic
community empowerment	resource consumption	reduced costs
social cohesion	GHGs emissions	local jobs
	local RES	revenues
	responsible use of resources	opportunities for companies
		invest in local generation

6.2.2. Energy City Hall

Energy City Hall is the first renewable EC in Italy, established under Law 8/2020 on energy communities in December 2020 [116]. It is located in the municipality of Magliano Alpi, and involves public buildings (municipal headquarters, library, sports centre, and schools), residential users, and small- and medium-sized enterprises. The project was initiated thanks to the initiatives led by the Energy Center of the Polytechnic University of Turin (Energy Community Manifesto for an active centrality of the Citizen in the new energy market [117]) and the Piedmont Region (through the already mentioned law for the promotion of energy communities [114]), with the aim of experimenting with participatory models and new configurations of RES production and consumption, building economic opportunities for stakeholders and benefiting citizens. The main supporters are the mayor of the Municipality of Magliano Alpi and local businesses (professionals and plant operators working in the area). The Magliano Alpi Community developed due to special conditions and within a developing legislative and regulatory framework, and therefore does not represent a replicable model. The economic and energy performance during its first year of operation was analysed by Ghiani et al. [118].

From the experience gained, the promoters of Energy City Hall are developing new EC and cooperative models to support territorial development. The actors involved and the various initiatives in progress, which include the design of energy communities consisting of aggregations of municipalities, partnerships between public and private entities, industrial clusters, and so on, are referred to as "Magliano & Friends".

The BM of Energy City Hall is that of the community prosumerism.

The new initiatives are third party, community prosumer or flexibility aggregation. The main impacts of Energy City Hall are reported in Table 10.

Table 10. Main impacts of Energy City Hall.

Social	Environmental	Economic
community empowerment	resource consumption GHGs emissions local RES	reduced costs local jobs revenues opportunities for companies invest in local generation

6.3. Energy Cooperative Hindelang—Germany

In Germany, the first EC initiatives date back to the 20th century [84]. Germany has been favoured in adopting the directives in the national regulatory framework, since natural persons were already authorised under the previous legislation to participate in the electricity market [119], thanks to the adoption of the Renewable Energy Act (Erneuerbare-Energien-Gesetz—EEG) in 2000 [120] and the energy market liberalisation. More specifically, the EEG was originally motivated to encourage renewable energy production through the adoption of the incentive rate; however, the fed-in-tariff was gradually phased out in the following amendment in 2017, which also included, for the first time, the definition of "citizens' energy corporation" (Bürgerenergiegesellschaften). The goal of this legal entity is the support of the connection of different plants in order to overcome the technical and economic limits of small-scale plants, also through economic incentives [84]. The last amendment of the Renewable Energy Act, released in July 2022 (and concluded at the beginning of January 2023) [121], updated the regulation of "citizens energy corporations" as an approximation of the European REC and characterised at least by 50 natural persons. In addition, among other requirements, at least 75 percent of the voting rights is held by natural persons located within a geographical radius of 50 km from the energy plant.

This last case study is different from the previous ones, mainly due to its longer history, but also because of specific elements that are related to its evolution over the years.

Energy cooperative Hindelang (EWH) [122] was founded as a cooperative to initiate the production of energy from hydropower for local communities one hundred years ago.

EWH does not comply with the definitions of RECs and CECs of the European directives and operates on the market as a utility.

The cooperative has more than 300 members, mostly residential users and SMEs. The municipality is part of the cooperative but has no direct decisional role. Being a private entity, EWH is fast and flexible in the implementation of the decisions, without the burdens of bureaucracy that often characterise public authorities. The cooperative would like to implement a LEM, but it is currently not possible due to the German market structure and the existing national regulations.

The EWH value propositions are in line with REC models; it operates for the benefit of its members but not necessarily from an economic point of view, taking into account the social sustainability dimensions.

The BM is the one of energy cooperatives. The main impacts of EWH are reported in Table 11.

Table 11. Main impacts of EWH.

Social	Environmental	Economic
community empowerment social capital	resource consumption GHGs emissions pollutant emissions and impacts local RES	reduced costs local jobs opportunities for companies affordable energy costs invest in local generation

7. Discussion

The main elements constituting a comprehensive, albeit simplified, model of ECs, discussed in this review paper, are schematically represented in Figure 4. Each of them must be adequately considered in order to design and implement ECs capable of producing positive effects on society and the environment and not only in terms of covering plant installation costs or deliver economic profits.

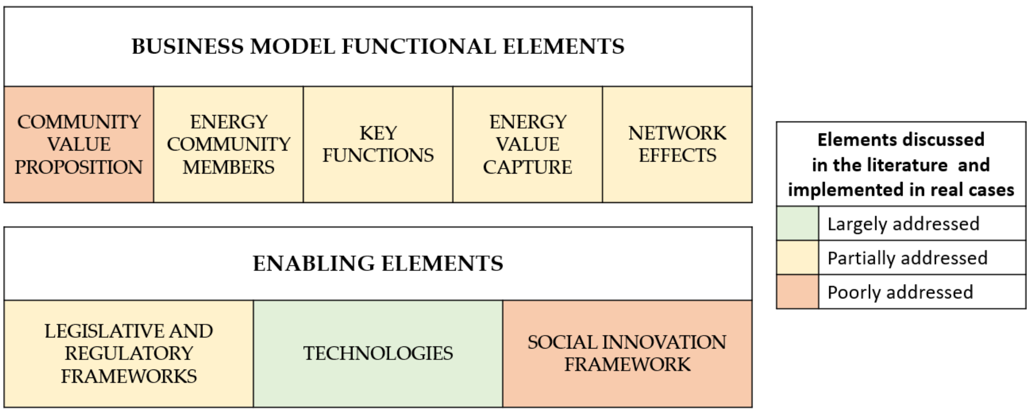

Figure 4. Study model of energy communities (authors' elaboration) and classification of the elements by how they are addressed in the literature.

In the scheme, we also indicated the level of depth and comprehensiveness with which functional and enabling elements are addressed in the literature and implemented. The colour green is used to indicate the elements that are extensively addressed, for which there appears to be limited research needs and which are widely adopted in the initiatives developed. The colour yellow is used to indicate elements for which there is a need for more in-depth theoretical and/or empirical investigation, or which have not yet been adequately implemented. The regulatory framework falls into this category. Although it is dealt with extensively in the literature, it is still under development in practice. Finally, elements that require further research development and to which insufficient attention seems to be devoted at the application level are indicated in orange. This table clearly shows that most of the aspects that we investigated require further attention and development.

It should be pointed out that the elements that constitute the enabling dimensions may have different levels of maturity in European countries. This is particularly true with regard to the legislative and regulatory environment, with some countries having already completed the transposition process of EU Directives and defined an enabling regulatory framework, while others are still in an early stage. In addition to bridging legislative and regulatory gaps, there is a need to implement measures to promote the inclusive participation and equal representation of all citizens, and monitoring actions to assess the actual impacts of ECs implementation.

What emerges significantly from the analysis is the call for the greater consolidation of models suitable for accompanying the transition to more sustainable models, which requires a cross-sectoral and multidisciplinary approach to the subject of ECs. At the technological level, on the other hand, the context is mature, with some gaps regarding monitoring and management systems. ECs must be asked to develop their WBs with a focus on socio-economic and environmental priorities instead of profit priorities, in order to be able to generate value for community members along the three components of sustainability as stipulated by EU directives.

It is, therefore, essential to carefully define value propositions by assessing the trade-off between the various benefits according to the specificities of each context to avoid the misalignment of goals and interests, competition and tensions between actors, and an imbalance towards the economic component. The actual impacts of ECs along the different dimensions should be monitored and assessed to verify that they actually deliver the expected benefits. This fundamental step is required to ensure that ECs actually lead to the desired results, and to highlight potential negative impacts and adopt the necessary measures.

The analysis of the experiences of ECs from the literature and case studies revealed also the importance of the role of favourable factors or exogenous factors in supporting successful initiatives. These include the availability of successful pilots and models to build upon; supporting frameworks from regions and local entities; economic resources to cover start-up costs; having a centralised management entity; the strong willingness of proponents and local public authorities (e.g., mayors and presidents of unions of municipalities); and the availability of tools (e.g., knowledge exchange platforms, self-assessment tools, toolkit with service packaging for helping municipalities in initiating the planning, and implementation of ECs). Remarkably, it was reported that the vision of the promoters and their determination were in many cases the driving elements that enabled initiatives to be developed even in the absence of fully mature enabling elements.

Several possible risks associated with the development of ECs were identified, including the following that are worth highlighting:

- New inequalities may be produced and existing ones accentuated;
- Rebound effects may offset expected environmental benefits: people who already feel virtuous because they are in the REC may be inclined to consume energy less carefully;
- There may be a failure of the whole EC model.

The last risk is potentially the most impacting, as it may undermine the main reason for implementing the EC, and may occur for several reasons, including the following:

- Initiatives developed by using copy-and-paste BMs, driven by the incentives from National Recovery and Resilience Plans and EU targets and not by the motivation to build real sustainable change;
- Inadequate expertise and knowledge of market functioning of proponents and managing entities;
- The speed at which the EC phenomenon is progressing in practice is too fast compared to the establishment of a solid theoretical basis;
- Excessively high expectation of cost reduction or revenues;

- Unpreparedness to change one's consumption habits and demand for a continuous and unlimited availability of energy, which is not compatible with REC operating patterns;
- Increased bureaucratic and administrative burdens following the full transposition of EU directives.

Three basic needs therefore emerge at the policy level: (1) to define a clear and stable legislative and regulatory environment; (2) to define appropriate forms of economic support to accompany the emergence and start-up of durable initiatives (without fueling bubble phenomena); and (3) to promote ECs also on the basis of quantified social benefits, and not only of economic and environmental ones, reinforcing the principles of diversity and inclusion of marginalised and vulnerable groups.

Three main areas emerge with regard to research developments: (1) empirical analyses and monitoring campaigns in order to quantify the energy and economic savings of energy communities in real operating conditions and the related environmental benefits; (2) the definition of robust and shared methodologies and KPIs for measuring the social impact of initiatives; and (3) expanding the body of research on social innovation processes and sustainability transitions.

8. Conclusions

ECs are being increasingly seen as a tool to support the decarbonisation of energy systems, thanks to their potential to coordinate distributed energy generation and consumption. Along with environmental and economic benefits, ECs are expected to provide also social benefits in terms of energy justice, energy democracy, community empowerment and social capital. However, the positive impacts of ECs cannot be taken for granted.

In this review, we gathered evidence from the literature and some real case studies to provide a framework for analysing the benefits of ECs, with a focus on the European context. The analysis of the main enabling factors for the creation of ECs highlighted the need for further investigation in the field of social innovation and for a clearer and more simplified definition of the legislative and regulatory framework. At the same time, all the functional elements of the business model still require better investigation, in particular, the definition of a clear and consensual value proposition.

The potential of ECs is promising but there is still a lack of shared methodologies and clear evidence from research, analysis and experimentation to prove that they represent a sustainable and replicable model to achieve social and environmental objectives as well as economic stability. The need for initiatives to be supported by adequate accompanying measures, monitoring and policy guidance to ensure that they deliver the expected benefits is also noted. Indeed, change towards sustainability requires an integrated approach between technological and social innovation as well as the support and representation of all members of society.

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Abbreviations

The following abbreviations are used in this manuscript:

ACV	Association Centrales Villageoises
AURA-EE	Auvergne-Rhône-Alpes Regional Energy Agency
BM	business model
CEC	citizen energy community
CV	Centrales Villageoises
DER	distributed energy resources
DR	demand response
DSM	demand side management
DSO	distribution system operator
EC	energy community
ECBM	energy community business model
ED	energy democracy
EEG	Erneuerbare-Energien-Gesetz
EJ	energy justice
EU	European Union
ESCO	energy services company
EV	electric vehicle
EWH	Electricity works Hindelang
GHG	greenhouse gas
IEMD	Internal Electricity Market Directive
KPI	key performance indicator
LEM	local energy market
P2P	peer-to-peer
PPA	power purchase agreement
PV	photovoltaic
REC	renewable energy community
RED	Renewable Energy Directive
SG	smart grids
SME	small- and medium-sized enterprise

Appendix A. Interview Questions

The interviews were conducted through web calls and e-mail exchanges with the contact persons of the ECs. The questions investigated the stages of the creation and operation of the EC and future prospects, in terms of both needs and possible risks resulting from the transposition of European directives [23,25] at the national level and associated initiatives.

1. Who are the initiators/founders?
2. What were their motivations?
3. What contextual factors favoured its birth? Has its development been influenced by any exogenous factor?
4. What were the main supporters?
5. Have you considered social impacts on the local communities affected by the EC/cooperative?
6. Have you considered and estimated possible present and future externalities (both positive and negative) in the cost/benefit analysis?
7. What are the members and their motivations for joining it? Has there been an evolution over the years? Have some members left the EC/cooperative?
8. What are the main costs and benefits of joining the EC/cooperative? Beyond the ones known in literature (savings on bills for members, creation of added value and jobs), indirect impacts (the contacts and methods of coordination between the subjects of the territory experimented within the CERs and the collaboration with other relevant local actors (Public entities, companies, etc.) have triggered virtuous processes of shared construction of strategies and actions for local development).
9. What are the costs and benefits for the society?

10. What are the main challenges that you have faced so far?
11. Do you think that the creation of your EC/cooperative has had the effect of raising awareness on energy and environmental issues also among those not directly involved in it?
12. If you had the power, what would be the most important and urgent measures that you would implement to support ECs?
13. Do you see any risk for ECs in the transposition of the Clean Energy Package into national legislation?

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