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Review

A Review of Renewable Energy Communities: Concepts, Scope, Progress, Challenges, and Recommendations

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Abstract: In recent times, there has been a significant shift from centralized energy systems to decentralized ones. These systems aim to satisfy local energy needs using renewable resources within the community. This approach leads to decreased complexity and costs, improved efficiency, and enhanced local resilience and supports energy independence, thereby advancing the transition toward zero carbon emissions. Community energy plays a pivotal role globally, particularly in European countries, driven by citizen engagement in generating power from renewable sources. The European Union, known for its focus on social innovation and citizen participation, recognizes the essential role of energy communities in its latest energy strategy. The concept for creating local energy communities or community-based energy projects has gained worldwide attention, demonstrating the economic, environmental, and efficiency benefits for using renewable energy sources. However, there is a noticeable gap in research covering all the updated aspects of renewable energy communities. This article provides an in-depth review of energy communities, especially renewable energy communities, exploring their concepts, scope, benefits, and key activities. It also sheds light on their progress by presenting results and analyses. Some countries have shown significant advancement, others are in the initial stages, and a few have partially adopted REC implementation according to the Renewable Energy Directive II. Additionally, it discusses the main challenges and potential recommendations to enhance the growth of renewable energy communities. This work is a valuable resource, emphasizing the importance of citizen involvement and offering insights into various aspects of community energy for sustainable energy transition. It also provides practical insights and valuable information for policymakers, researchers, industry professionals, and community members who are keen on promoting sustainable, community-driven energy systems.

Keywords: energy community; renewable energy community; RED II directive; shared renewable energy

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1. Introduction

Environmental issues are becoming worse and soaring everywhere, which calls for the restructuring of society. Among these, one of the most insistent is the transformation of the energy paradigm, replacing non-renewable energy and pollution-creating sources with renewable energy sources (RESs), which are cleaner, more sustainable, and less resource intensive. Additionally, these advanced technologies have already been considered as reliable and economical [1,2]. RESs tackle pressing issues, such as promoting energy security, enhancing public health, fostering economic opportunities, and driving technological innovation. By shifting to renewable energy, societies can decrease their negative impact on the environment [3], promote sustainable development, and pave the way for a resilient and fair energy future [4]. The EU seeks to reach climate neutrality by 2050 as a means for mitigating climate change [5]. In recognizing the crucial part of the energy sector considering the climate crisis, the European Union's Clean Energy Package emphasizes that the energy mix ought to be from RESs and that the energy market ought to be rationalized, taking into consideration flexibility [6].

Over the past century, electricity industries around the globe have endured a revolution, moving toward predominantly large-scale centralized energy systems. This centralized structure has presented challenges in terms for accessing capital and efficiently operating interconnected power systems [7,8]. Conversely, there has been a paradigm shift, in recent years, in the power system because of the integration and management of growing RESs. This shift has resulted in a greater presence of decentralized energy resources within the grid. Decentralized energy systems provide local control, facilitating community-based energy generation and distribution at the local level [9]. These systems seek to satisfy the local energy demand utilizing distributed energy resources available within the community [10]. Local decentralized energy resources transport energy generation nearer to consumers, resulting in reduced cost, inefficiencies, and complexity; bolstering local resilience; promoting energy independence; and transitioning toward zero carbon emissions as compared to centralized energy systems [11]. Decentralized systems have the potential to drive innovation, empower individuals, and encourage community engagement. As a result, energy communities have emerged as cooperative strategies that facilitate the sharing of renewable energy within decentralized energy systems. These communities align with the goals for minimizing energy consumption and promoting flexible energy utilization by active consumers, thereby alleviating the high energy loads on the power grid [12]. Integrating local DERs and engaging local communities appears to be a promising initiative to address the transition of the local energy landscape effectively [13,14].

Apart from this, the energy community has made significant progress in Europe and is poised to be a foundational element in creating a further decentralized and adaptable energy union, where citizens gradually become more influential. The Renewable Energy Directive, also known as Directive (EU) 2018/2001, or RED II, commences the GHG emission criteria and sustainability goals in the European Union. It has also established a legally binding goal of 32% for the total percentage of energy from renewable sources in the EU's gross final energy consumption by 2030. This regulation created a standard framework for promoting the use of renewable energy sources [15]. With its annexation in the Clean Energy Package, Directive 2018/2001 RED II introduced the renewable energy community (REC) concept and its establishment, concentrating on the use of RESs, whereas 2019/944 ED directives presented the citizen energy community (CEC) concept, focusing on electricity, with the combined primary aim for delivering social, environmental, and economic advantages to their members [15,16]. These communities play a vital role in supporting individuals worldwide during the shift toward sustainable development and the utilization of RESs. Renewable energy communities offer a wide range of options to inspire the active involvement of community members, including the decision-making process, investment opportunities, ownership models, local energy conversation platforms, and economic inducements [17]. Individual households serve as the fundamental units within local communities. Local communities are well positioned to recognize local energy requirements and unite individuals toward shared objectives, such as self-sufficiency [18], resilience, autonomy [19,20], and sustainability [21]. Moreover, as local communities transition, their roles evolve from being mere consumers to becoming prosumers who actively engage in local generation, energy sharing, demand-response strategies, and energy efficiency measures [22].

In recent times, a global discourse has emerged surrounding energy autonomy, energy security, and energy poverty improvement policies in both developed and developing nations. Energy communities have appeared as substantial contributors to this discussion, as they facilitate the integration of DGs, particularly inside local energy systems. Many researchers are involved in and keen to work on and promote topics such as REC-like concepts [23,24], distributed energy technologies and their integration [25,26], design and modeling [27,28], energy sharing [29,30], economic and feasibility analyses [31,32], policies and policymakers [33,34], challenges [34,35], comparison between countries [36,37], business models [38,39], community and social acceptance [28], prosumer and consumer roles [40,41], self-consumption [42], and many others. All these topics are discussed individually in different articles. However, the authors have not covered all the core topics of RECs. Moreover, the review papers that were published in 2019–2023 are presented with titles in Table 1.

Table 1. Review articles published on RECs, as per the European Directive (2019–2023).

S No.	Reference	Year	Papers with EC and REC Titles
1	[43]	2023	A review and mapping exercise of energy community regulatory challenges in European member states based on a survey of collective energy actors
2	[44]	2021	The challenges of engaging island communities: Lessons on renewable energy from a review of 17 case studies
3	[45]	2023	A typology of business models for energy communities: Current and emerging design options
4	[46]	2021	Towards data-driven energy communities: A review of open-source datasets, models, and tools
5	[47]	2023	The Emerging Trends of Renewable Energy Communities' Development in Italy
6	[48]	2020	Renewable energy communities as 'socio-legal institutions': A normative frame for energy decentralization?
7	[49]	2021	Social arrangements, technical designs, and impacts of energy communities: A review
8	[50]	2020	Regulatory challenges and opportunities for collective renewable energy prosumers in the EU
9	[51]	2021	A transition perspective on Energy Communities: A systematic literature review and research agenda
10	[52]	2021	Business models for energy communities: A review of key issues and trends
11	[33]	2021	Implementing a just renewable energy transition: Policy advice for transposing the new European rules for renewable energy communities
12	[53]	2019	Social innovation in community energy in Europe: A review of the evidence
13	[54]	2021	Do renewable energy communities deliver energy justice? Exploring insights from 71 European cases

It should be noted here that there are very few review articles relevant to the renewable energy community according to the RED II Directive and a lack of articles on the main topics to be discussed, like the progress of REC implementation in different countries of Europe, general and technical challenges associated with this slow progress, policies, policymakers, awareness, and future recommendations to boost this progress across Europe to involve the community to create and own RE projects for sustainable transition. Keeping in view this scenario and the emerging topic of renewable energy communities, this research work aims to fill this gap by covering all the parts of RECs, including the concepts, scope, benefits, activities, progress, challenges, and recommendations. Moreover, this article provides an updated, complete review of energy communities, serving as a valuable resource for researchers, policymakers, communities, and practitioners seeking to understand the concepts, progress, challenges, and potential solutions in this field. The motivation behind this emerging topic is to provide a comprehensive analysis of this emerging concept and its potential to drive the transition toward sustainable and community-driven energy systems. Motivations should be as diverse as the communities' actions, such as social and environmental values that support their dedication to sustainability, worries about climate change, the shift to renewable energy sources, legislative incentives, and financial considerations, like solving social equity and poverty problems in some areas. This paper covers all the parts of RECs, investigating and discussing several aspects, from concepts to future recommendations, filling the gap on important topics relevant to RECs. The rest of this paper is organized into seven sections as follows: Section 1 discusses motivations, related works, and contributions; Section 2 highlights the role of the energy community, the concept of the energy community, and the renewable energy community as per the RED II Directive; Section 3 discusses the scope and benefits in accordance with RECs; Section 4 describes the participants and activities carried out, including technological components, like energy generation, energy consumption, ESSs, energy sharing, energy-monitoring and efficiency measures, and virtual power plants. Moreover, an illustration of an REC is also included for further clarification. This part plays an important role for all the researchers, participants, and other stakeholders to become familiar with these components, resulting in awareness regarding the economic, environmental, and social benefits. Section 5 elaborates on the progress and challenges along with some barriers associated with the energy community; Section 6 concludes the overall work, and Section 7 gives the future recommendations to be considered for successful RECs.

2. Concept of Renewable Energy Communities

Energy communities are pivotal in Europe's energy transition, attracting private investment, gaining public support for energy projects, and facilitating long-term renewable resource utilization. This leads to reduced electricity costs, decreased pollution, and a boost in local economies through job creation, ultimately empowering citizens to actively drive the energy transition [55,56]. Simultaneously, redirecting profits back into society enhances the social acceptance of sustainable development and the expansion of renewable energy. Linguistically, the term "community" refers to a social unit illustrated by shared customs, values, and a collective sense of place [57]. From an energy perspective, an "SEC" or "sustainable energy community" refers to a group of energy utilities, either publicly, privately, or jointly owned and operated within a specified geographical area. In this setup, end-users (citizens, companies, and public administrations) come together to fulfill their energy requirements through a collaborative approach. A variety of definitions and terms exist in the literature for RE initiatives led by citizens and localities, as shown in Figure 1 [8,21,22,37,58–61].

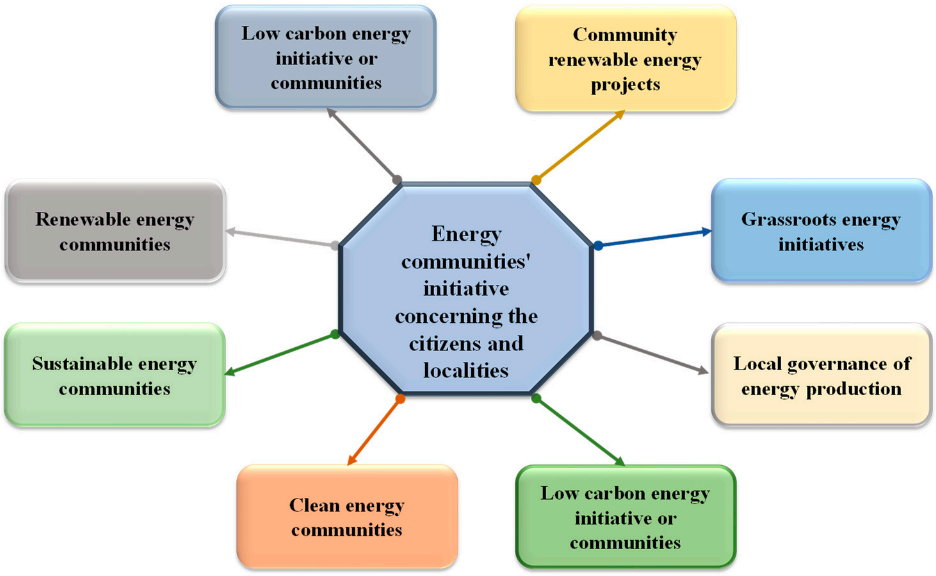

Figure 1. Types of energy communities and various terms for initiatives led by localities [8,21,22,37,58–61].

The terms given in the figure appear to cover a range of programs or activities pertaining to community-based initiatives focused on developing low-carbon and renewable energy projects. Even though the initiatives' objectives could occasionally overlap, each word may have distinct meanings or concentrate on various facets of community involvement in sustainable energy practices. Although encouraging clean energy and sustainable behaviors at the community level is the same goal of all the types, there are some distinctions among them in terms of particular areas of emphasis, such as project execution, governance frameworks, or the overall reach of sustainability programs. The terminology used may also represent contextual or regional differences in language and policy emphasis.

As local communities progressively engage in the ownership, decision-making, and organization of energy generation plants [62,63], a new socio-energy system centered on DGs from RESs is evolving. The shift toward establishing renewable-powered communities has been thrusted owing to various economic and environmental concerns related to conventional energy consumption. The EC is divided as centralized, decentralized, and distributed, classifying the associates' identities and aim [8]. Bruno Canizes et al. [64] discussed ECs and classified them as homogenous energy communities (HECs), mixed energy communities (MECs), and self-sufficient energy communities (SECs). Herein, the main term, 'net energy', differentiates all the parts. The E_{Net} value is the difference between E_g and E_c within a specified timeframe. In the following subsections, a more detailed description is reported. A negative value indicates a negative net energy ($E_c > E_g$). Conversely, a positive value indicates a positive net energy ($E_c < E_g$).

2.1. HECs

HECs are characterized by a group of members whose E_{Net} is consistently either positive or negative during the defined time, i.e., $E_{Net} < 0$ or $E_{Net} > 0$. E_{Net} is the difference between E_g and E_c within a specified timeframe. Two variables are required to identify the various HECs in the electrical network: the geographical distance among the members (D) and E_{Net}. The problem for recognizing the EC may be viewed as a grouping problem according to D, and the HEC's net energy can be aggregated. The relevant equation for the HEC is given as follows [64]:

$$\sum_{i=1}^{N} E_{Net} = E_{Net_1}(t) + E_{Net_2}(t) + E_{Net_3}(t) \ldots\ldots\ldots + E_{Net_N}(t) \tag{1}$$

2.2. MECs

MECs consist of members with mixed net energies, including both positive ($E_{Net} > 0$) and negative values ($E_{Net} < 0$). The members within the community have surplus energy ($E_{Net} > 0$) that they can share or store, while others have a deficit ($E_{Net} < 0$) and require energy from the grid. This creates an opportunity for these members to come together and form an MEC. In an MEC, the surplus energy from some members can be shared with those in deficit. This arrangement benefits both parties; members with negative $E_{Net}(t)$ can access cheaper energy, while members with positive $E_{Net}(t)$ can enhance the profitability of their production units by selling their extra energy [64].

2.3. SECs

SECs comprise members whose total net energy is positive, regardless of the individual E_{Net} of each member. In SECs, the collective generation surpasses the overall consumption, leading to self-sufficiency in the energy supply. The SEC falls within the category of MECs but with a significant distinction: Like MECs, SECs consist of members with both positive and negative $E(t)$ values. Nevertheless, the key difference lies in the SEC's ability to fully balance their energy demand with locally generated energy from their own generation units, primarily utilized for self-consumption. This unique characteristic of SECs, where $E_{Net} > 0$, makes them particularly intriguing for study. These communities are highly interesting because they rely less on the electricity grid, ensuring greater energy independence and resilience. SEC members enjoy several advantages, such as being unaffected by contingencies in the main grid. Their self-sufficiency in the energy supply makes them more secure during emergencies or disruptions in the larger power network. As a result, studying SECs offers valuable insights into sustainable and resilient energy community models.

Figure 2 compares the energy communities according to their net energy. HECs are comprised solely of members with either $E_{Net} > 0$ or $E_{Net} < 0$. The first part of the HEC shows the positive value, and the other part of the figure presents the negative value after the addition, which is mentioned as resulting in $E_{Net} > 0$ and $E_{Net} < 0$. As per the constraints set by the authors, if E_{Net} is positive, it cannot exceed a positive upper value, and if E_{Net}

is negative, it cannot be less than a negative lower value. In contrast, MECs consist of members with both negative and positive net energies. Lastly, special energy communities (SECs) are formed by members whose total net energy ($\Sigma\ E_{Net}(t)$) is greater than zero [64].

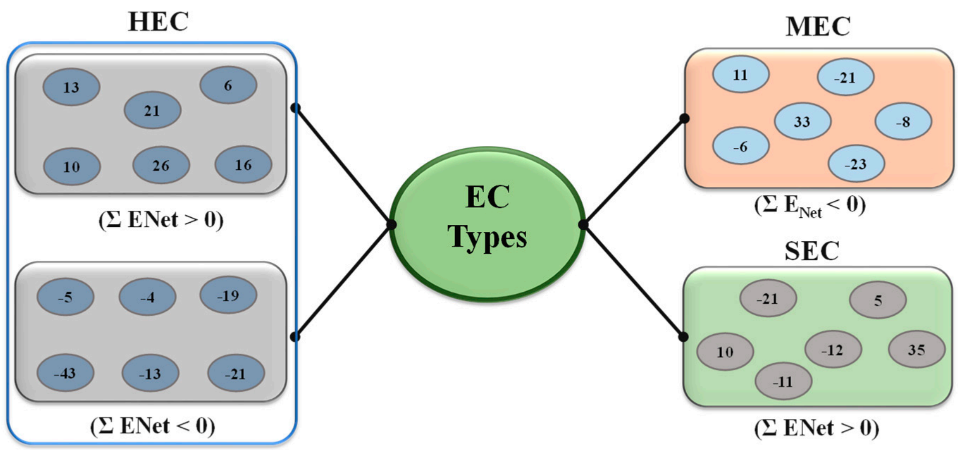

Figure 2. Types of energy communities.

Continuing with this aspect, more recently, these energy communities' innovative concepts have received explicit attention in the various standards and directives encompassed by the Clean Energy for All Europeans Package. Consequently, two distinct categories of ECs [65,66] can be identified: CECs represented by Directive 2019/944 [16] and RECs presented by Directive 2018/2001 [15]. To contribute to the attainment of energy and climate objectives actively and effectively, the creation of both CECs and RECs can play a vital role. The ultimate goal is to attain advantages in terms of cost efficiency, sustainability, and safety [67]. RECs are poised to play a critical role in driving the transformation of the whole energy system and market. Simultaneously, these initiatives directly benefit citizens by enhancing energy efficiency, leading to reduced electricity costs and creating local job opportunities and economic growth [68,69]. RECs are identified as a pivotal factor in promoting the wider implementation of onsite RESs. Diverse RETs, like solar PVs, wind, and biomass, have been actively encouraged in recent years to pave the path toward a sustainable energy future [70,71]. Within RECs, consumers will be able to produce, store, use, sell, and share energy. RECs have emerged as an innovative and cooperative strategy to facilitate the sharing of renewable energy among participants [72,73], resulting in reduced energy costs and lower economic costs for infrastructure and services, contributing to climate change mitigation efforts, and fostering a sense of community spirit [55,74]. Also, RECs aim to reduce individual energy consumption, optimize grid loading, and leverage the energy flexibility of active consumers [75].

3. Scope and Benefits of RECs

3.1. Scope

Recently, there has been a notable swell in interest in the concept of local ECs generating as well as supplying energy, accompanied by parallel developments in smart grid technology. This growing fascination has captivated the attention of individuals interested in implementing local energy systems [76]. As a result, communities in both developed and developing countries are undergoing a transformation, stimulating their conventional status as passive consumers and embracing a new role as active "prosumers"—individuals who generate energy as well as consume it [77]. The definition and scope of energy communities are centered on the idea of citizens engaging in local production and governance of renewable energy [78]. The public's acceptance of RE projects and the promotion of the clean energy transition in local communities are greatly aided by citizen-driven energy and collective actions that put residents at the forefront [79,80]. The scope of ECs extends beyond energy generation, encompassing social, economic, and policy dimensions that foster community empowerment and contribute to the transition to a sustainable and cleaner energy source in the future [81,82]. Apart from this, community energy represents a distinct subset of ECs distinguished by the active participation of local communities, which may take on roles as investors or contributors in these projects [83]. Moreover, the scope of ECs can be classified based on various other factors, such as their organizational structure, geographical scope, municipal bodies, households, rural and agricultural communities, private businesses, public institutions, cooperatives, and even farms [84], as presented in Figure 3.

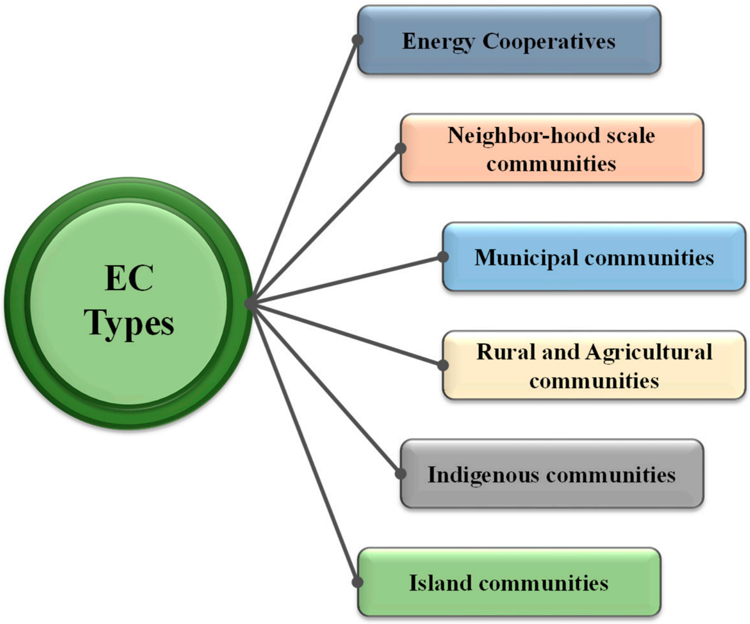

Figure 3. Scope of energy communities as per applications.

Energy cooperatives enable communities to collectively invest in renewable energy installations and share in the generated benefits [85]. Cooperatives primarily aim to provide goods or services to their members, and they differ from investor-owned businesses as their objective is not centered on distributing profits in accordance with the level of investment [86]. Cooperatives have emerged as a significant driving force in advancing the adoption of REs in many countries. Neighborhood-scale communities focus on a specific neighborhood or district within a larger community that has to localize renewable energy generation and consumption within a limited geographical area [87]. The concept of a neighborhood is presented at a scale that brings together individuals and their surroundings [88]. By harnessing local resources and engaging residents, neighborhood-scale RECs can create a sense of community ownership and promote sustainable energy practices, resulting in a significant impact on the realization of zero-energy objectives [89,90].

Municipal communities involve local governments taking the lead in developing and implementing renewable energy initiatives within their jurisdictions, and indeed, this aspect often receives the most focus [91]. These communities prioritize local renewable energy generation and energy efficiency measures and often integrate sustainable transportation and infrastructure planning. The researcher introduces a methodology to identify key urban regions where the municipal urban project could promote the establishment of RECs, minimize the restrictions on their formation, and maximize their social and energy benefits [92]. In rural and agricultural communities [93], RESs, like wind, solar, or biomass, can be utilized. They focus on promoting renewable energy installations on farmlands, rural properties, or agricultural facilities. Rural and agricultural RECs can contribute to income diversification for farmers, energy self-sufficiency, and sustainable rural development [94,95]. Indigenous communities have shown a growing interest in developing RECs that align with their cultural values, traditions, and land stewardship principles. These

RECs prioritize indigenous ownership, control, and benefit sharing in renewable energy projects. Indigenous RECs often focus on promoting renewable energy solutions that are culturally appropriate, address energy poverty, and contribute to community resilience [96].

Island communities, particularly those reliant on imported fossil fuels, are increasingly establishing RECs to transition to local renewable energy sources. Island RECs aim to enhance energy security, reduce reliance on imported fuels, and promote environmental sustainability [97]. These communities often combine RE generation with ESS and smart grid technologies to establish resilient and self-sufficient energy systems. Energy planning for islands is complicated by their restricted resource availability, which hinders efforts to establish self-sufficiency and sustainability in their energy systems [98]. Researchers focus on the primary emphasis of this article, which lies in addressing the difficulties associated with deploying RESs within the context of a small island scenario [99,100]. Hrvoje Dorotić et al. [101] introduced an innovative strategy to outline the energy framework of a carbon-neutral island. These above classifications highlight the diversity and adaptability of energy communities, showcasing how they can tailor their approach based on local characteristics, goals, and resources. Regardless of the type, all the RECs share a common vision for promoting renewable energy, community participation, and sustainable development.

3.2. *Benefits*

The primary goal is to contribute to the establishment of a green energy system to give social, environmental, and economic benefits to its stakeholders or participants [61]. ECs, as a gross route of innovation [102], encompass the localized production of renewable energy, citizen engagement and governance, and the pursuit of a sustainable energy system [103]. Ceglia et al. [104] highlight the key benefits as energy vectors, procurement cost reductions, quality supply improvement and reliability, and the citizens' active involvement and use of local resources. Moreover, a comprehensive categorization of EC benefits has been established and is represented in Figure 4 [105,106].

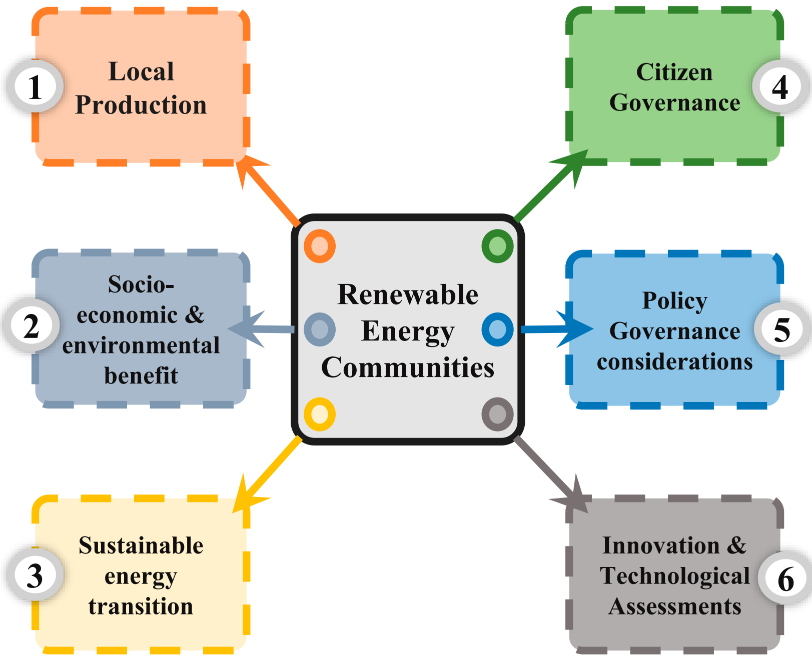

Figure 4. Representation of REC benefits [104,105].

3.2.1. Local Production

RECs focus on generating RESs at the local level. They involve the installation and management of citizen-owned production units, which can range from solar panels on individual homes to larger-scale community projects, like wind farms or biomass plants.

3.2.2. Socioeconomic and Environmental Benefits

RECs offer socioeconomic advantages, including decreased energy costs, opportunities for job creation, enhanced local resilience, better energy security, and stronger social cohesion [107,108]. They also provide socioenvironmental benefits [109,110] by reducing air pollution and improving local air quality through displacing fossil-fuel-based energy generation. This emphasizes the shared objectives of sustainable energy production and consumption.

3.2.3. Sustainable Energy Transition

ECs play a vital role in advancing the shift to a green energy system. By promoting generation from RESs and reducing reliance on fossil fuels, they contribute to decarbonization efforts, energy independence, and the overall mitigation of climate change [111,112]. In this way, energy communities contribute to achieving renewable energy targets.

3.2.4. Citizen Governance

Energy communities empower citizens by enabling their active involvement in the energy sector. Citizens can become prosumers, generating their own energy and participating in local energy production and consumption decisions. This collaborative method fosters engagement, a sense of ownership, and obligation among citizens, aligning with the EU's objectives for citizen-centered and inclusive energy policies.

3.2.5. Policy Governance and Considerations

Energy communities are influenced by policies and regulations at various levels, including national, regional, and local. Governments play an essential role in creating an enabling context that supports establishing and operating ECs. Governance structures within energy communities can vary, ranging from informal grassroots initiatives to formalized legal entities.

3.2.6. Innovation and Technological Assessments

Energy communities deploy new and innovative technologies in the energy sector. They offer a testing ground for emerging technologies, for instance, energy storage, smart grids [113], and demand-response systems. This supports the EU's objectives for promoting clean energy innovation and fostering technological advancements.

4. Main Activities of RECs

This section discusses the main stakeholders and participants who can jointly work together to form an REC. The activities of these participants include energy generation, ESSs, energy consumption, energy selling, and energy sharing. Moreover, an REC example is illustrated for further discussion. Forming an REC is not convenient for a person or a family. Many stakeholders play vital roles in forming an REC. A diverse range of actors from both the private and public sectors may participate to varying degrees, contributing to or forming a cohesive community [114,115]. Citizen engagement in decision-making and RE projects can potentially enhance the acceptance and adoption of renewable energy sources. However, RECs consist of citizens as volunteers, investors, or participants; an energy-community's local citizens [116], social entrepreneurs, community organizations, and public authorities [117] come together, jointly participating in the energy transition [118,119]. Moreover, these endeavors play a major role in facilitating the shift to a decreased-GHG-emission energy system, enhancing consumer engagement and trust, offering valuable flexibility in the market, decision-making, and local trading [120]. Active participation, local involvement, and co-ownership play crucial roles in bolstering energy communities [121]. The roles of these participants may vary, but collectively, they are contributing to the development, management, and success of the REC. It is important to mention, here, the role of all the participants, so Table 2 is added, which highlights the main participants and their roles in the REC.

Table 2. REC participants and their roles.

Participant	Participant's Role
Citizens [68]	• They actively participate in decision-making activities of energy-related projects, including the planning, development, and management of RE projects. Also, they can contribute by investing in and utilizing RESs within the community. • It should be mentioned that not every citizen may choose to take part in the REC; those who do not actively engage take on the role of consumers within the community.
Local Businesses	• Local businesses within the community play a vital role in the REC by investing in RE projects, providing goods and services related to clean energy technologies, and contributing to sustainable economic growth.
Local Government	• The local government is crucial to supporting and regulating the REC. It can facilitate permits and regulations for renewable energy projects, provide incentives and policies to encourage RE adoption, and collaborate with other stakeholders to achieve sustainable energy goals.
Investors [68]	• This group of actors plays a significant role in establishing the REC by providing investments. However, they do not consume any energy generated within the REC. As non-prosumer co-owners, they actively contribute to the REC's development and can include financial institutions, strategic investors (e.g., banks), as well as individuals, like citizens and landlords.
Prosumers (Energy Producers and Consumers)	• This group of actors within the community becomes a part of the REC, assuming roles as prosumers. Energy producers and consumers in the REC are responsible for generating REs through various technologies (PVs, wind, biomass, etc.) and utilizing the energy generated by the above technologies. Some passive consumers can take supply from the grid.
Energy System Actors [68]	• These actors are responsible for ensuring the stability and equilibrium of the local energy system while overseeing the movement of energy into and out of the REC. Moreover, they could encompass energy suppliers, which can be private sectors, commercial or public utility companies, as well as the DSO. Their roles are essential in maintaining smooth operation and efficient energy distribution within the REC.
Energy Cooperatives/ Community Organizations	• Energy cooperatives or community organizations may be formed to facilitate collective decision-making, the pooling of resources, and collaboration among community members to implement and maintain RE projects.

Considering the roles of the main participants, the diverse range of the collective energy in an energy community includes energy generation, electricity distribution, energy supply, aggregation, energy consumption, energy sharing, energy storage, the provision of energy-related services, and other technologies, as represented in Figure 5 [68].

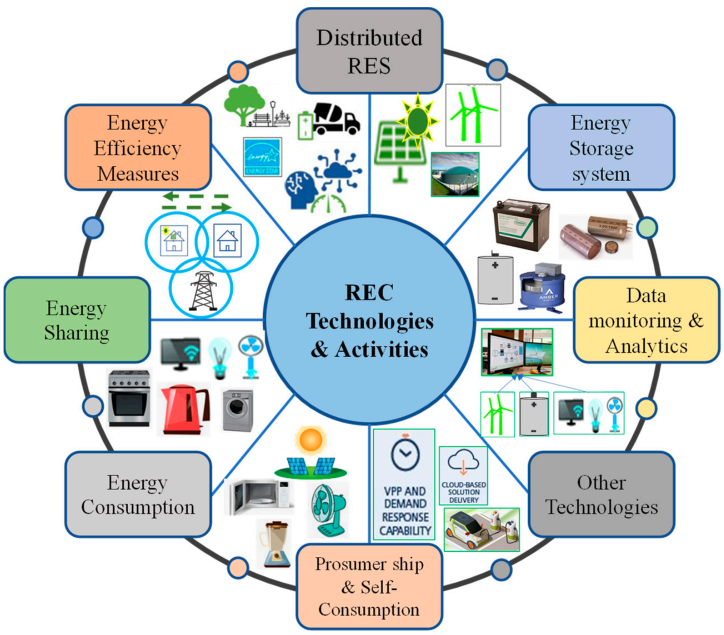

Figure 5. Main activities of RECs.

4.1. Energy Generation through Renewable Energy Sources

Incorporating distributed generation from renewable sources yields societal advantages and holds the capability to enhance the functioning of distribution networks [122,123]. These systems, including from small-generation units to multi-energy centers, incorporate elements like RESs and other hybrid systems like PVs and thermoelectric systems [124]. Nonetheless, research concerning the integration of these systems within community settings is limited, especially in relation to the involvement of local stakeholders, like community energy utilities, ownership aspects, and the spatial extent of the implementation. This gap hinders the acceleration of DES adoption [125]. Energy communities incorporate various RETs, like wind, solar PV systems, hydro, biomass, or geothermal systems. These installations produce clean energy locally, decreasing dependency on non-renewable energy sources and raising economic benefits [126]. The primary driving factor for the increasing preference for technologies like RES-based DGs is attributed to the environmental advantages they offer [127]. The pursuit of expanding renewable energy shares in the system, with a specific focus on the deployment of PVs, while sustaining increasing rates and transitioning away from FiT schemes, along with prioritizing prosumers, highlights the promising potential of energy communities [128,129]. PV systems have become dominant owing to their availability and ease of use on roofs for producing electricity. The equation for the instant power output for a PV system, as described in reference [130], is as follows:

$$P = A \cdot G \cdot n_c \cdot n_i \tag{2}$$

Moreover, diverse forms of community energy exist, including initiatives where local individuals come together to invest in renewable energy, such as wind farms or cooperatives [37,131]. Researchers emphasize the need to move beyond feed-in tariff schemes and, as an alternative, focus on expanding prosumer-intensive business models. Prosumers, who both consume and generate electricity, are at the core of these models, which are essential for sustaining the growth of PV energy generation rates [132]. Table 3 shows the characteristics of distributed renewable generation sources [133–135].

Table 3. Characteristics of DREs.

RET	Fuel Used	Size (kW)	Availability	O/P	Carbon Emissions
PVs	Sun	0.02–1000+	Location based	DC	Nil
Solar Thermal	Sun and Water	1000–30,000	Location based	DC	Low
Biomass Gasification	Biomass	100–20,000	-	-	Low
Geothermal	Hot Water	5000–100,000	Location based	Both	Low
Hydro (Small)	Water	5–100,000	Location based	AC	Nil
Wind	Wind	0.2–3000	Location based	AC	Nil
Ocean Energy	Ocean Waves	100–1000	Location based	AC	Low

4.2. Energy Consumption and Prosumer Role

Energy consumption is herein considered for the active consumer, the passive consumer, and the grid. One who generates electricity and consumes it from a self-generated plant via self-consumption is also known as a prosumer. The concept of the prosumer has become important in the new era after the development of smart grids, microgrids, and renewable energy communities. Alvin Toffler originally devised the term 'prosumer' in the 1980s by combining the words 'producer' and 'consumer' [136]. In the beginning, this term was employed to describe the fusion of producers and consumers facilitated by the digital revolution, but now it could have a variety of applications. L. Brand et al. [137] define the term as customers that both produce and consume direct heat. Energy communities foster the concept of "prosumers", who both consume as well as produce energy. P.G. Da Silva et al. [138] define it as a consumer having its own production capacity. P. Kästel et al. [139]

highlighted it as entities or houses that function as both energy producers and consumers simultaneously. Currently, RECs have encouraged consumers to become prosumers owing to various advantages in growth, including cost savings and energy independence. Community members are encouraged to become active participants in energy generation by installing renewable energy systems on their properties and contributing to the overall energy production of the community [140]. ECs and consumer co-ownership are essential keystones in REs, leading to a successful energy shift [141]. When consumers own RECs, they can be converted to prosumers, generating and consuming the energy [142]. PV producers utilize a portion of the electricity they generate, essentially serving as both consumers and producers of their own electricity [143]. This not only allows them to reduce their expenditure for energy but also obtains another income from selling the excess production [144]. Owing to these benefits, prosumership is attracting energy communities and is expected to be increasingly embedded, entailing a broad range of actors [145,146]. The relevant equations for REC energy consumption, production, and self-consumption are respectively given as follows [68]:

$$E_L = P_L.t \tag{3}$$

$$E_{pv} = P_{pv} \cdot t \tag{4}$$

$$E_{self-consumption} = \min\left[E_{load}(t,n), E_{pv}(t,n)\right] \tag{5}$$

4.3. Energy Storage Systems

The primary idea behind an energy storage system is to create a buffer for energy, serving as a storage intermediary between generation and consumption. An energy storage system refers to a device that is able to convert electrical energy into a storable form and subsequently transform it back to electricity as required [147]. ESSs, such as batteries, are essential components of energy communities. They allow the effective storage of extra energy produced during periods of peak production, which can then be used in periods of high demand or in the absence of active power generation from RESs [148]. ESS technologies are categorized into the foremost groups as mechanical, thermal, chemical, electrochemical, electrical, and others, like hybrid energy storage [149,150]. According to their response characteristics, ESSs can be characterized into three main groups: short term (ranging from seconds to minutes), employed for power quality enhancements; medium term (from minutes to hours), utilized for managing grid congestion and offering frequency responses; and extended long term (spanning from hours to days), applied for aligning supply and demand over extended timeframes [151]. The further subclassification of energy storage systems is given in Figure 6 [149,150,152].

A fundamental aspect of ECs is the inclusion of energy storage units. These units play a critical role in retaining a balance between supply and demand when DGs are operational. Owing to the intermittent nature of the majority of RESs, a significant challenge arises in maintaining a balance between energy generation and load for ensuring the stability and dependability of power networks. Extensive endeavors have been dedicated to exploring feasible remedies, encompassing EES, load adjustment through demand management, and integration with external grids. Of all the potential resolutions, electrical energy storage stands out as a particularly promising avenue [153]. In the current economic landscape, batteries emerge as a cost-effective option, despite having a relatively higher negative environmental impact compared to other storage technologies [154].

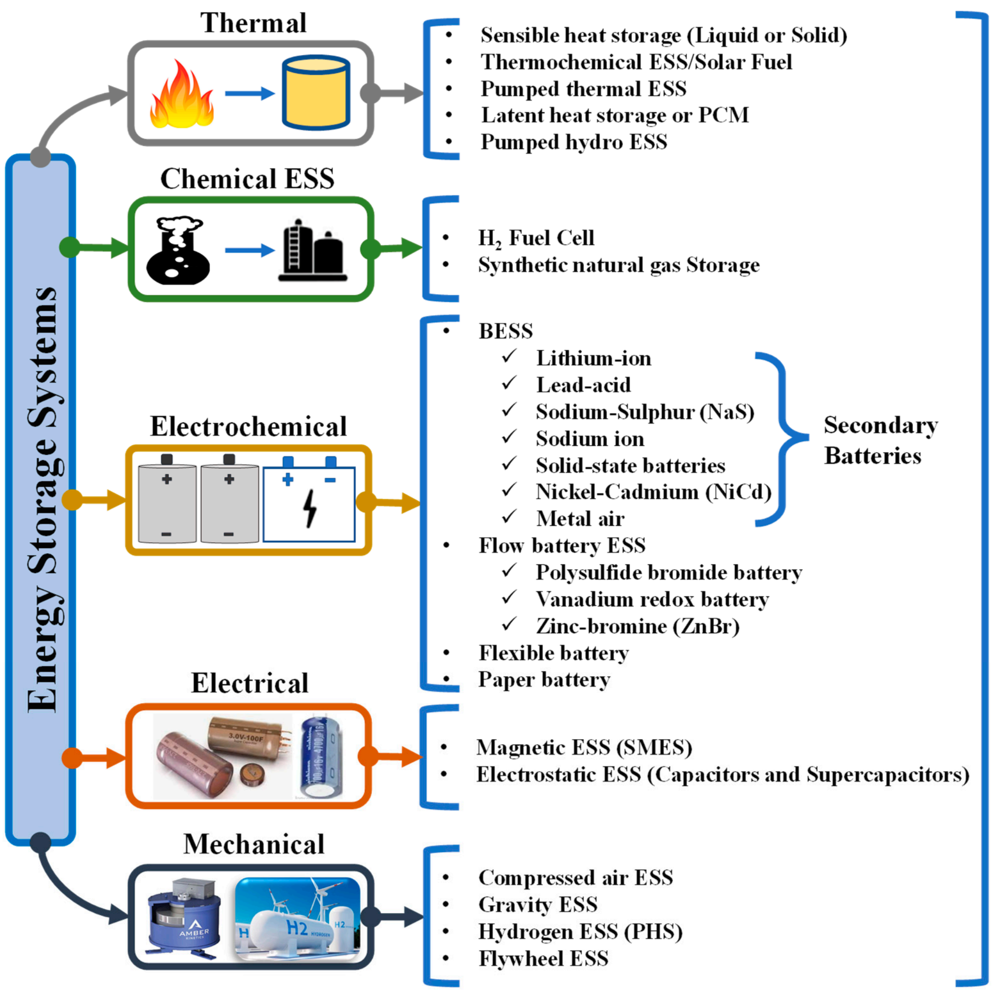

Figure 6. ESS technology classification [149,150,152].

4.4. Energy Sharing

The sharing of energy in renewable energy communities involves the collaborative distribution and utilization of locally generated DREs. The participants share the produced energy among themselves in cases of excess, fostering a decentralized and sustainable approach [155]. Energy sharing within communities transforms individual consumers into prosumers, allowing them to share surplus energy with other participants of the community. Community-level energy plans offer a superior prospect to tailor developed energy systems according to local states and specific constraints. This approach facilitates increased efficiency and the sustainable utilization of these RESs within the community [156]. Sharing could occur through many mechanisms, like community microgrids, peer-to-peer energy exchanges [157,158], or collective energy storage initiatives, by aiming to optimize the usage of RESs, promote a sense of community engagement, enhance energy resilience, and promote self-sufficiency in sustainable energy practices. The amount of shared energy within the community at time interval t can be computed as follows [68]:

$$E_{shared}(t) = \min\left(E_{surplus}(t), E_{deficit}(t)\right) \tag{6}$$

$$E_{surplus}(t) = E_{pv}(t) - E_{self-consumption}(t) \tag{7}$$

$$E_{deficit}(t) = E_{load}(t) - E_{self-consumption}(t) \tag{8}$$

Figure 7 shows the REC concept diagram and results from MATLAB software (R2021a) for two days for an REC located in a southern city in Italy, showing the load on the cabin, net power, and energy sharing. In the simulation, N_p = 2 prosumers and N_c = 2 consumers have been considered, evaluating the producibility using the PVGIS database [159] and load data from a daily load profile (residential) on an hourly basis.

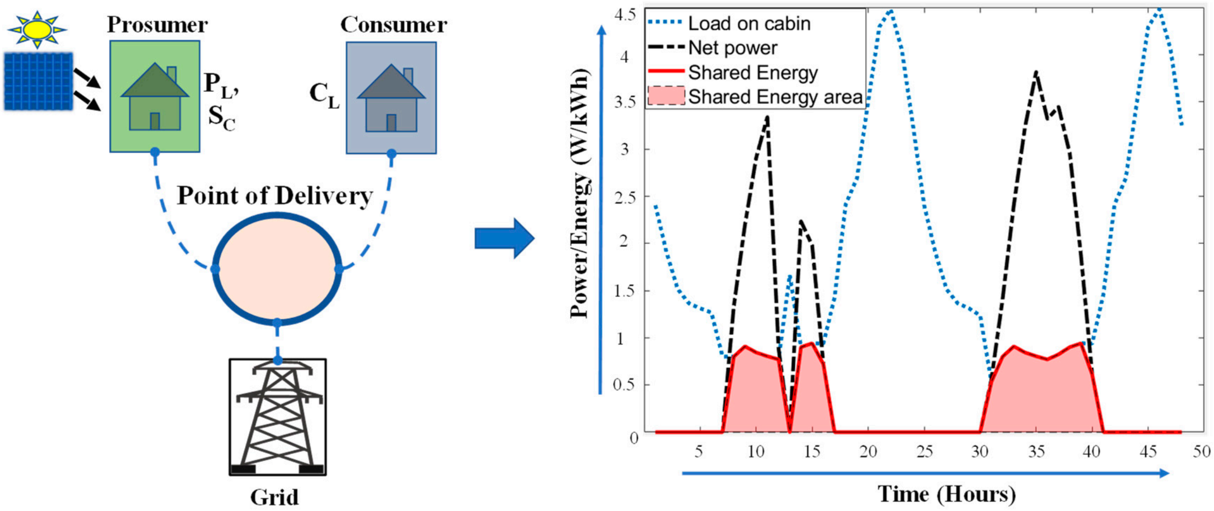

Figure 7. REC concept and shared energy.

Many researchers are involved in working on this advanced topic and have proposed sharing models and concepts [160,161]. G. Di Lorenzo et al. [162] proposed an innovative model for sharing the power produced by common generators and energy services. This model is appropriate for both multi-tenant structures and clusters of multiple buildings and is pertinent to both current as well as newly constructed buildings, having the advantages of scalability to larger systems and easy energy-storage integration. L. Martirano et al. [163] proposed a model for sharing power, named PSM, designed for energy communities to share energy and other services that are suitable at the building level and in larger communities. B. Fina et al. [164] examined the optimal installation capacities as well as economic feasibility of ECs compared with individual buildings, resulting in increased profitability in implementing a PV system with the optimum size as compared to the buildings.

4.5. Energy Efficiency Measures

Recently, there has been a notable surge in interest in the development of RECs, driven not only by the scientific community but also by their documentation of actual and simulated case studies showcasing various energy-sharing system setups owing to their many advantages [165]. Specifically, the expansion of ECs has the potential to result in energy conservation, enhance energy efficiency, and contribute to the alleviation of "energy poverty" [166]. ECs emphasize energy efficiency and encourage the installation and operation of energy-efficient technologies and practices among community members because the energy shift rests on two fundamental pillars: energy efficiency and the adoption of RESs [167]. This not only necessitates a change from fossil fuels to RESs but also involves preventing energy wastage and elevating levels of energy efficiency [168,169]. The technologies include energy-efficient appliances, building design, and insulation, and behavior changes are aimed at reducing the overall energy consumption [170]. F. Coonan et al. [171] offer deeper insights into evaluating strategies and steps for guiding homeowners to attain energy savings and reduce carbon emissions. Also, they highlight the potential of RECs as a fresh approach for addressing energy efficiency in existing housing, along with potential enhancements in their energy performance. C. Chen et al. [172] have presented an artificial-intelligence-driven evaluation model called AIEM, aimed at predicting the economic effects of REs and energy efficiency. This innovative model has the potential to boost energy efficiency and optimize the utilization of RESs.

4.6. Data Monitoring and Analytics

Energy communities utilize data monitoring and analytics tools to track energy production, consumption patterns, and the overall system performance [173]. This data-driven approach helps to identify optimization opportunities, make updated decisions, and ensure the efficient operation of the EC. L. Gagliardelli et al. [174] proposed the energy community data platform (ECDP), a middleware platform specifically crafted for gathering and analyzing extensive data on energy consumption within local ECs, with the primary goals for promoting greater awareness and conscientious energy usage among users. Online information sources play a crucial role in engaging people and raising awareness concerning the advantages of energy communities. Researchers examine online news data to gauge public awareness and the media's significance regarding this subject and employ an innovative measure called the semantic brand score (SBS), which links text mining techniques and social network analysis [175]. Z.D. Grève et al. [42] proposed data analytics modules to assist community members in optimizing their resource usage (generation and consumption) to reduce their electricity costs. M. Sănduleac et al. [176] recommend the integration of data collected at significantly varying reporting frequencies to enhance the system's situational awareness and improve the monitoring accuracy because distribution power grids face partial observability issues, primarily stemming from inadequate metering infrastructure, particularly in areas downstream from medium-voltage substations. S.M. Patil et al. [177] discussed their proposed system involving the real-time presentation of solar energy utilization, facilitated by a Raspberry Pi and Flask framework. This smart monitoring platform offers daily insights into renewable energy consumption, aiding users in analyzing their energy usage and its impacts on renewable energy utilization and electricity concerns.

4.7. Virtual Power Plants

Virtual communities, or power plants, leverage digital platforms and technologies to enable energy sharing and trading across a wider geographical area. They connect renewable energy producers with consumers who may be located remotely but share a common interest in supporting renewable energy. Virtual RECs facilitate P2P energy transactions, allowing individuals to buy and sell renewable energy credits or join in community solar projects. Kalle Pesonen et al. [178] examine the notion of a decentralized virtual energy community comprising six rural Finnish farms. This is achieved through an exploration of their current and projected electricity generation, as well as demand-responsive resources created through electrical equipment. Kwang Y. Lee et al. [179] introduce a P2P energy-trading model that optimizes green energy transactions, considering the preferences of prosumers and consumers, focusing on the cost-effective operation of the virtual energy community, reducing storage depreciation, and enhancing social welfare by promoting energy trading.

All the above components are considered as one of the major parts of RECs to know about RES technologies. In the literature, most of the research articles cover RES technologies, ESSs, and energy consumption, like those in microgrids. However, in the case of RECs, other terms are added, such as self-consumption, prosumership, and energy-sharing concepts. In addition, the other parts that must be considered are energy monitoring, data analytics, and VPPs, as these parts are important in tracking and monitoring the data of energy consumption, energy sharing, self-consumption, and PV production and to check the economic benefits. All the data are analyzed on an hourly basis. Furthermore, an illustration is also given in the next section to clarify the concept, different consumers (active and passive), prosumers, grid connection, and flow of energy in cases of energy excess and deficit within RECs.

4.8. Illustration of Activities in an REC

Furthermore, an illustration of the activities in an REC is shown in Figure 8 for clarification. The REC consists of many parts, including (a) the grid/traditional energy system; (b) the supply to passive consumers from the grid; (c) apartments having their own generation and sharing their energy with the community and grid in the case of excess feed; (d) sharing of energy with houses H1, H2, H3, and H4 and the other buildings, school, and grid in the case of excess power; (e) the school generating electricity from wind and solar PV systems with battery sources and treated as a prosumer sharing the generated electricity with the community and grid in the case of excess power; and (f) the supply from the grid to consumers who will not generate their own electricity and may not be interested in taking part in the community.

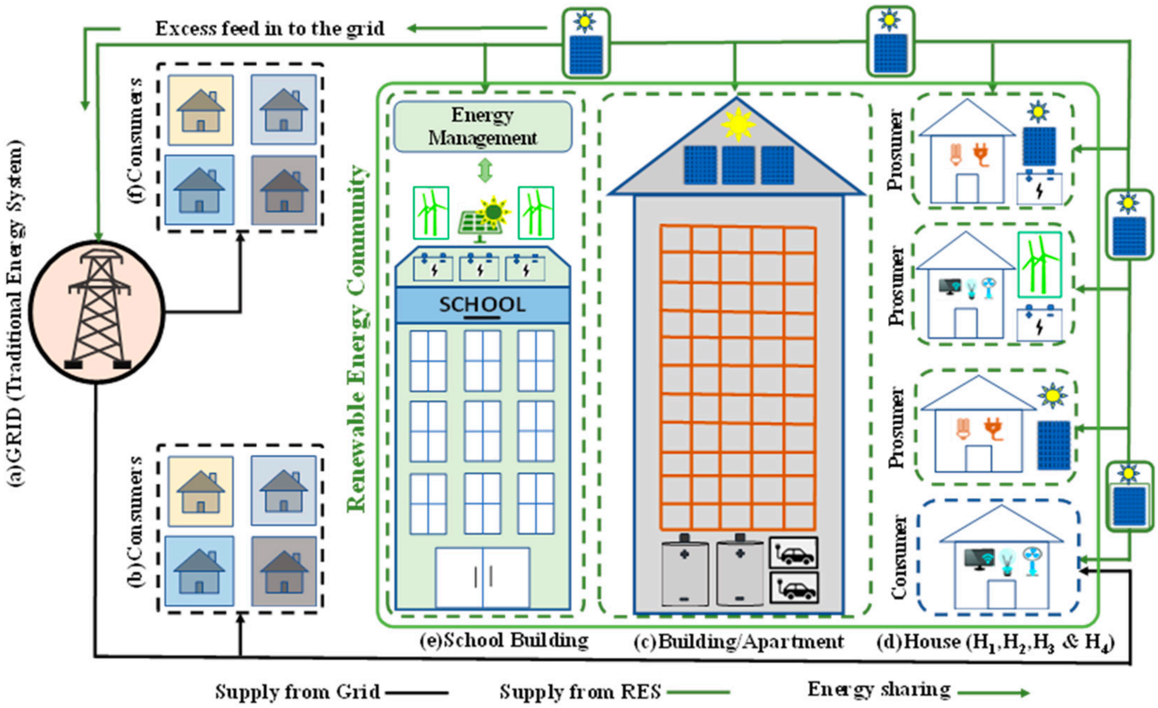

Figure 8. REC and energy flow within the community and to the grid.

Energy generation is the main part of the REC. The generation could be from wind, solar, biomass, etc. Most of the participants jointly invest in PV system plants used to produce electricity owing to their availability and excess potential in many countries. In Figure 8, the generation is from a solar PV system and wind power. House-01 (H1), considered as a prosumer, produces electricity from a solar PV system, and a battery bank is also connected for charging to use at night. House-02 (H2) is considered as a prosumer because it produces electricity from a wind system. House-03 (H3) is also considered as a prosumer that produces electricity from a solar PV system without any battery backup. In part (c), there is a large building, including apartments, that produces electricity from a solar PV system, including a battery backup, and has an EV-charging station. Part (e) contains the building of the school, including energy production from a wind plant and a solar PV system with a battery bank, and part (a) is the grid/traditional energy system. This can generate electricity from non-renewable energy resources or fossil fuels.

Considering the energy consumption, it could be from the consumer side, the prosumer side (self-consumption), or grid consumption. The consumer side means those consumers who either consume energy from the grid or via the community. Self-consumption means that the actors within a building directly utilize the electricity that is generated onsite. Lastly, when the generated PV energy is not enough to meet the demand within the REC, the REC can supplement its energy needs by procuring electricity from the grid. Consumers who choose not to participate in the REC can still receive their energy supply from the grid.

According to the energy-sharing concept, actors share extra energy after consuming their load (self-consumption) to meet the demand inside the community. In Figure 8, the green line shows the REC, and the line outside the boundary shows the sharing of energy from one to another, and in cases of excess, the energy will feed into the grid. Energy storage could be a major part of the REC because it helps to store energy that can be utilized at night or in the case of any disturbance. In the figure, House-01, House-02, and the building/apartments and school contain energy storage systems. When energy is in excess or exceeds the demand of the REC, the excess energy could be supplied to the public grid, introducing the grid feed-in concept. Referring to the figure, H1, H2, H3, and the school and building/apartment are power producers and considered as a part of the REC. In cases when the generation is higher than the demand, the energy from these prosumers will feed into the grid. In fact, it is a considerable advantage to the prosumers for obtaining an amount of money from the energy sold to the grid. Moreover, other services, like flexibility, could be applied by the EC, like shifting loads when the onsite PV production is high, resulting in high self-consumption. This will allow the community to offer implicit flexibility [68,180].

The above concept can be further extended to simulations using software, like MATLAB/Simulink, and a real-time REC to analyze the results in detail. E. Cutore et al. [181] focused on the design phase of an REC, considering the performance and economic benefits by presenting the optimization model for the regulations in Italy. A. Hussain et al. [182] considered various cases of residential communities to increase the consumption from RESs. They also considered three cases for their study: community ESSs, local ESSs, and internal trading. However, our future work will continue on the same topic, using MATLAB/Simulink and considering the optimal design of the REC with different consumers and prosumers, proper monitoring, and analytics to check the technical parameters on an hourly basis and the economic benefits at the specified time in the REC. An example of a time-dependent simulation is provided in Figure 7.

5. Progress and Challenges

5.1. Progress

The notion of an energy community has gained momentum as a grassroots movement over the past decade in various countries, particularly in Europe and North America, including the United Kingdom, the Netherlands, and Ontario, Canada [20,55,183,184]. As per reference [84], there are more than 420 energy communities in Great Britain. In Brooklyn, New York, citizens, and shopkeepers that take part in the local EC can purchase and sell renewable energy on an app. In Australia, where around 100 ECs now operate, the first to be established was at Hepburn Wind, which began to generate energy in 2011. In Japan, the ECs are widespread, exploiting mainly solar energy. In achieving the EU's energy transition goals, energy communities are emerging as a key element. Half of European citizens could produce half of the EU's REs, as per the European Commission, by 2050. Within the EU countries, there are 9252 ECs, but notable disparities exist among the member countries. Germany leads with 4848 energy communities, surpassing the other EU states. In contrast, Bulgaria, Malta, Romania, and Hungary have a very low number of energy communities. Germany has a high share of energy communities, as shown in Figure 9 [185], and has achieved one of the highest counts of ECs in Europe [186], boasting around 900 renewable energy cooperatives [187]. Germany has not completely incorporated the EU regulations for energy communities into its national legislation. The country has a substantial history of citizen-financed projects, broadly categorized as energy communities. Cooperatives, with a deeply rooted tradition in Germany, oversee approximately 1000 operations of renewable energy plants [188]. Italy currently has approximately twenty active or in-progress renewable energy communities scattered throughout the country, with an additional seven in the planning stages, as per the report titled *Renewables Communities 2021* made by the Italian association Legambiente [189]. In the report it has been shown that the self-production facilities are predominantly in the range from 20 to 60 kW.

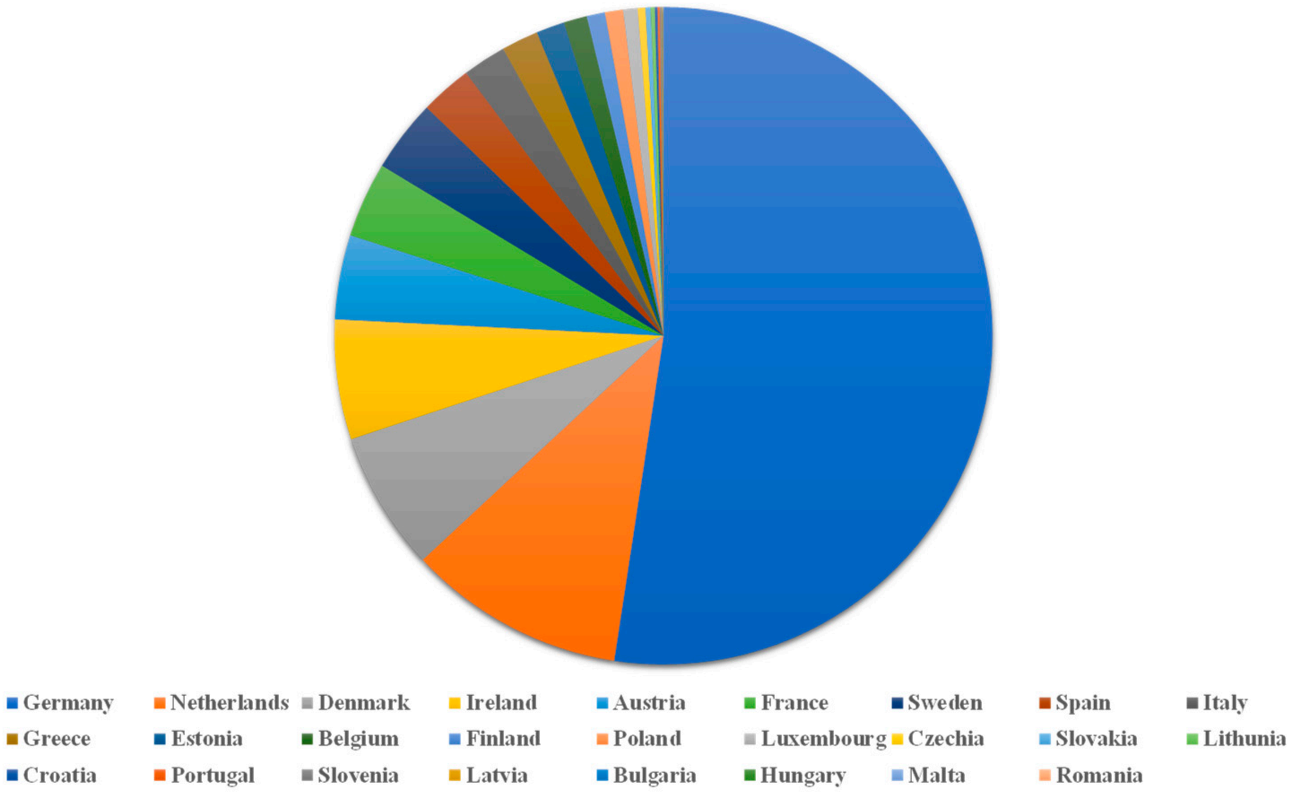

Figure 9. European countries' energy community statuses.

As per the European Union's Joint Research Center, in 2020, the highest numbers of energy communities were in Germany, Denmark, and the Netherlands, with 1750, 700, and 500 energy communities, respectively [84]. As per the report of 2021 in reference [190], the data relevant to the REC transposition, as per RED II in European states, are given in the first part of Table 4 which is updated from the report. Among the nine countries analyzed, some have shown good progress, some partial, and some are at the bottom line. Italy has shown good progress in transposing and implementing the RED II provision for RECs. However, Germany, standing as one of the countries leading the way in the field of community energy, has shown little progress so far. Belgium and Italy have either partly or fully addressed the RED II provision, as per their obligations. Spain, Portugal, and the Netherlands have also shown good progress; nevertheless, all the other countries have yet to transpose and implement the RED II provision. F.D. Minuto et al. [191] have also provided the details of EU countries where the EC support mechanism exists, as presented in the second part of Table 4. It can be seen that incentive mechanisms are different in different countries. The authors in reference [192] documented the latest advancements in global P2P pilot initiatives. Concurrently, numerous countries have achieved a high level of maturity in the development of virtual energy-metering policies [193], which are not spreading in EU countries [120]. Moreover, as per the NREL, the implementation of diverse legislation and incentive mechanisms across several U.S. states to support the virtual metering framework facilitates EC projects [194].

Table 4. Characteristics of DREs.

Description/Progress	Countries								
	IT	ES	PT	NL	BE	DE	LV	PL	NO
Transposition Status of RECs in 9 EU/EEA Member States [190]									
RECs have a legal definition.	green	green	green	grey	grey	orange	grey	orange	orange
Definition of RECs follow-up as per the RED II guidelines.	green	green	grey	grey	grey	orange	grey	orange	orange
Renewable energy communities are legally allowed to generate, store, and sell REs as well as share that energy within the REC. (Here RE is considered as energy generated by the REC.)	green	grey	green	green	green	orange	grey	grey	orange
Final customers (especially residential customers) are allowed to take part in RECs.	green	grey	green	green	green	orange	grey	grey	orange
The government (national or regional) conducts an evaluation of the potential for REC development as well as the current obstacles.	green	grey	grey	orange	grey	orange	orange	green	orange
The government considers the requirements of RECs when creating support programs to compete equally with other market players for support.	orange	orange	orange	grey	grey	grey	orange	grey	orange
The government gives any framework that makes it possible to promote and support the creation of RECs.	grey	grey	grey	grey	grey	grey	orange	grey	orange
EU Member States' EC Support Mechanism [195–198]									
Beneficiary of support scheme									
EC management	√			-		√	-	-	-
Members (net billing)		√	√	-	√		-	-	-
Incentivized energy quota									
Shared energy	√	√	√	-	√	√	-	-	-
Energy supplied to the grid	√	√	√	-	-	√	-	-	-
Network charges	√	-	√	-	-	√	-	-	-
Time considered for shared energy									
1 h	√	√	-	-	-	√	-	-	-
1/4 h	-	-	√	-	√	-	-	-	-
Incentive mechanism type									
Virtual self-consumption	√	-	-	-	-	√	-	-	-
Virtual net metering	-	√	√	-	√	√	-	-	-
FiT	-	-		-	-	√	-	-	-
Exemption	-	-	√	-	-	√	-	-	-
Bilateral contract	-	-	√	-	-	-	-	-	-
Net purchase and sale	√	√		-	-	-	-	-	-
FIP	√			-	-	-	-	-	-
Grants		√		-	-	-	-	-	-

[Flanders; ☐ (orange) = No/Insufficient transposition; ☐ (green) = sufficiently transposed; ☐ (grey) = partly transposed/transposition ongoing; IT = Italy; DE = Germany; BE = Belgium; ES = Spain; LV = Latvia; PT = Portugal; NL = the Netherlands; PL = Poland; NO = Norway.]

Furthermore, the research progress relevant to RECs at these sites was checked for three years, from 2021 to 2023, as mentioned in Table 5 in the annexure to the last part of this paper. From a research point of view, very slow progress has been made since the REC policy was highlighted in 2019. Research has mostly been carried out on economic analysis, optimization techniques for designs and modeling, energy management systems, energy-sharing models, benefit distribution among members, the environmental side, the optimal sizes of communities, RES technologies, distributed generation, comparisons among countries, sensitivity analyses, and so on. Researchers have highlighted the positive impacts of, and benefits associated with RECs, like decreased CO_2 emissions and increased economic benefits. From the table, it is observed that most of the research has been carried out for the country of Italy and is growing as per their regulations and framework. Moreover, from the papers that in the literature, simulation work has been conducted using assumed data or real-time data on loads and PV production, and the results were then used for economic assessments. However, the research lacks the monitoring part to check the profiles of consumption, self-consumption, and energy sharing on an hourly basis and a half-hourly basis so that consumers and prosumers may be familiar with and know their energy utilization and the associated benefits. Another main concern is that real cases, which are not discussed in the literature for the references cited in Table 5, should be considered as a priority for policymakers to show the REC prototype and enable the market to further clarify the concept of RECs and the benefits for its participants, resulting in the increased public acceptance and growth of RECs in Europe. Apart from this, to the best of our knowledge, comprehensive and specific reports on RECs in the EU are limited, which is attributed to the continuous development of legislation among EU member states. However, from the existing literature, energy communities have shown relevant progress in many countries, and some are working to adopt the EU framework. Many researchers and countries are involved in boosting progress by increasing the number of RECs in European countries, as per RED II directives. This work is continued by researchers, and there are challenges and barriers that could be the result of the slow progress of RECs, as considered in the next section.

5.2. Challenges

The literature shows many advantages of RECs, like the involvement of citizens and economic and environmental benefits. However, there are still many challenges [43,199], like policy challenges, regulatory and legal barriers, financing and funding issues, technical limitations and grid integration issues, social acceptance, community participation, capacity building, unequal distribution of costs and benefits, and knowledge sharing, that should be mitigated. Many authors have focused on these topics to address the challenges associated with RECs, including policy and regulatory [34,200,201], energy market regulations, grid connection and interconnection rules, the potential effects of ECs on MV distribution networks, financial policies, ownership, collective RE prosumers in the EU [50], business models [52], and governance models. These authors have reviewed energy communities governed by European-level regulations extending to the national legislation of selected European countries. Regulatory developments have been compared to European legislation, and a survey has been conducted. The reports suggest that the participation in energy-based activities and achievement of renewable targets are the preliminary motivations rather than the economic benefits [43]. L. De Almeida et al. [202] contributed by providing scenarios for different issues relevant to P2P trading and found that the trading market design and implementation are difficult challenges for ECs. In [203], the authors focused on the social acceptance of the RE project implementation and proved that it was a significant barrier in Europe. M. Krug et al. [56] examined the transposition of RECs in accordance with the RED II directive in Italy and Germany, highlighting the severe challenges relevant to administrative bottlenecks in planning and authorization processes to mainstream the CE and RECs and suggesting the necessity to increase the coordination between national and regional governments. As per the research article that considered nine countries in Europe [50], the author suggested that the laws pertaining to collective self-consumption are insufficient to give RECs a strong legal foundation. RECs need a specialized legal framework owing to the complexity of their requirements (such as DSM schemes and organizational structures) and obstacles (such as equipment costs and grid charges). A. Dimovski et al. [204] considered the Italian case study focusing on the impacts of ECs on the grid using simulations and found unequivocally that ECs had a significant impact on the grid. Specifically, the grid may have more losses, a deteriorated voltage profile, and higher line loads. In [57], the authors pointed out that the absence of social data in the EC database increases the difficulty and risk associated with implementing CESP. In [205], the authors addressed several challenges that must be considered to increase P2P sharing for linked communities in electricity markets. These challenges are the coexistence of diverse parties, limitations, losses, and management inside the network, uncertainty following the settlement, and affordable privacy and security. In [43], the authors emphasized that the main challenge and driving forces behind energy community efforts are not economic gains but rather reaching renewable targets and engaging in energy-based social activities, like increasing energy efficiency. All the above literature highlights the challenges related to ECs, which must be considered in future work by researchers and could be a supportive resource.

In addition to these challenges, there are many barriers that also cause slower progress. Another report, [206], highlighted the barriers in different countries to the implementation of the REC legislation, including smart meter operation and the obtained data, grid connection barriers, like the need for network operators to expedite processes, the addition of new systems to the existing grid, IT and communication technology installations in the grid, no possibility of an REC connection for all the distribution networks, time-consuming activities, administrative issues, economic and social issues, regulatory and legal issues, and the complexity at the initial stage of the REC, as shown in Figure 10. C. Sebi et al. [207] also discussed the barriers for France as institutional, market, organizational, and behavioral. They also highlighted the grid connection barriers pertaining to community REs in France. Moreover, other barriers include customers' unwillingness to alter their consumption habits, particularly if they are not involved in the changing process of the energy system [208]; the complexity in monitoring and controlling the new energy system [209]; and cost issues due to new technological components [210].

Table 5. Published articles relevant to RECs (2021–2023).

Ref.	Focus/Highlights	Software/Simulation/Other	Country	Benefits/Recommendations
[30]	Optimization for supporting REC investment, electricity-sharing management, and sensitivity analysis	Simulation	-	Deployment of RESs; generation and decarbonization of energy systems
[181]	Optimization model (size and flow management of RECs); energy performance assessment	MATLAB/Simulation	Italy	Reductions in carbon emissions and energy poverty and increased economic benefits
[211]	Governance model formalization to empower EC members; implementation of RECs	-	Itay	Good for creating ECs
[212]	Modelling and optimization of RECs; algorithm for operation of cells coupled to RESs	MATLAB/Simulation	-	Focus on increasing REC economic savings
[213]	Less development of RECs; applied actor–network theory approach	-	Italy	Best for all the actors for fostering REC initiatives and developments
[214]	Optimization of RECs to consider economic and environmental factors	-	-	Low paybacks and high avoided-CO_2-emission results
[215]	Development of an EMS, optimization, and sensitivity analysis	Simulation	-	Precious tool for supporting system operators in decision-making
[216]	Energy self-consumption in RECs; mathematical model; multi-criteria decision-making methods	Simulation	-	Economic gains; decrease in GHG emissions; self-sufficiency improvements; major rise in job creation
[217]	Economic assessment; investigation of the feasibility of a hydrogen power-to-gas system inside an REC	Simulation	Italy	Feasible to generate and market up to approximately 3 tons/year of green hydrogen, adhering to the current minimum selling price
[218]	Optimization of open-loop control problem in a receding horizon fashion; testing of algorithms on REC control problems	Real Case Data and Simulation	-	The overall cost of members' electricity bills significantly decreased

Table 5. *Cont.*

Ref.	Focus/Highlights	Software/Simulation/Other	Country	Benefits/Recommendations
[219]	Technoeconomic analysis; real case study; collective self-consumption; smart BMS; optimal BMS based on perfect forecasts	Bottom-up Simulation Software	Italy	Improved energy independence from the national grid; the highest possible energy independence and economic return
[220]	Novel management mechanism to enable preference-based energy sharing, optimization, and behavioral economics	Simulation	-	Efficacy of the proposed plan to lower energy expenses and enhance energy sharing among end-users
[166]	Analysis of energy-sharing directives; energy, environmental, and economic analyses; comparison of efficient users' system and conventional single users	HOMER Software (2016)	EU and Italy	Avoided 39.5 t/y of CO_2 with respect to the old configuration by not considering sharing approach; RES local SC index of EC outcomes greater than sharing mechanism in new directive
[56]	REC transposition; MLG analysis; methods of descriptive (legal) studies; comparison and progress in both countries	-	Germany and Italy	Dynamic and encouraged transposition in Italy, as per RED II; sluggish and fragmented in Germany
[32]	Operational and investment optimization; DSM; linear bottom-up optimization model; impact on environment and economic analysis	Python	Italy	REC contributes to a clean energy transition; implementation of fairness index concerning equitable distribution
[221]	Analysis of EC; district-heating networks; energy sharing; self-sufficiency; self-consumption	iVN simulation tool (for 2021)	Italy	Suggested design can enhance the system performance; PV integration decreases primary energy demand, and EC system reduces emissions
[222]	Development of a new hybrid AI method; predictive control of a stochastic model	Simulation	-	The method achieved an increase in the community's income by up to 18.72%
[223]	REC operation, investigation, and analysis of grid friendliness; participants' shares and economic benefits	-	-	Needs a minimal additional incentive for grid friendliness in reducing peak power; might be an economical way
[224]	Economic feasibility evaluation; optimization; multi-energy mixed-integer linear model	-	Flanders, Belgium	EC can achieve a cost reduction of up to 26% against business-as-usual cases; only 4–6% cost reduction compared to individual prosumers
[225]	The development of a conceptual framework; a qualitative comparative analysis	MaxQDA software	Germany	Organization type is crucial for successful energy shift, and cognitive legitimacy depends on geographical vicinity to successful projects
[191]	Virtual net metering in ECs; the redistribution of gains among community participants; sharing approaches	Simulation/Python Architecture	-	Sharing system influences the fair remuneration of profits; temporal load profile of users has an impact on the redistribution of profits
[226]	Quantifying effects of static and dynamic electricity allocations in ECs, determining economic feasibility of EC participation	Simulation	-	Dynamic allocation enhances the efficiency of electricity utilization as compared to static allocation, benefiting all the participants
[227]	Novel optimization strategies for RECs; advanced mixed-integer linear programming model	-	Austria	Reductions in community costs by 15% and community carbon emissions by 34%
[38]	Optimization of energy management with storage; multicriteria sizing of PVs and batteries; environmental assessment	StoRES/Simulation	Italy	Business model results show positive returns on REC investment; 2020 regulatory framework can help RES diffusion
[228]	Evaluating the willingness to participate in an REC; an extended model of theory of planned behavior; analysis of data on participants	-	Belgium	Good links are observed between attitudes (toward REs, environmental, and financial) and willingness to change behavior and attitude toward RECs

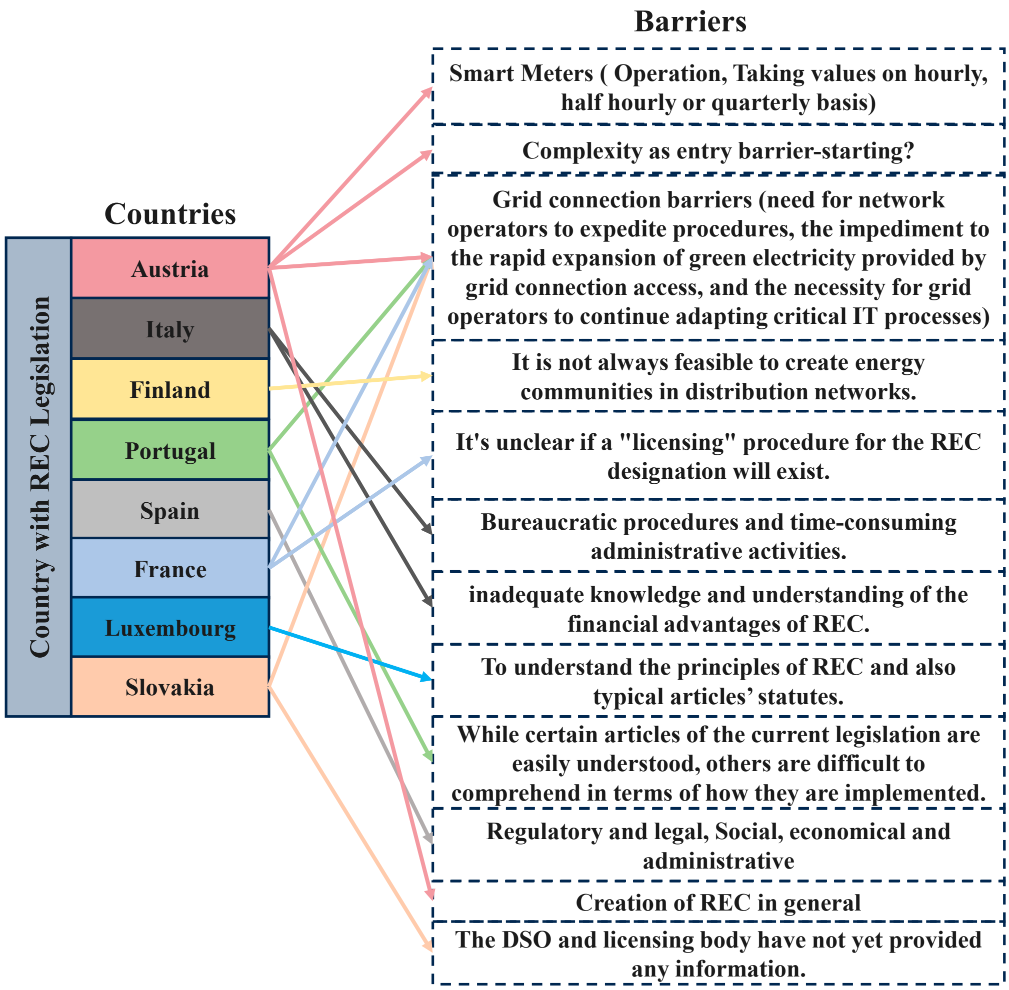

Figure 10. Barriers to REC implementation by country.

6. Conclusions

This review article has provided a comprehensive analysis of renewable energy communities and their concepts, benefits, types as per different application locations and cooperatives, technological components relevant to energy efficiency measures, DREs, energy storage and energy monitoring, progress, challenges, and future directions. RECs offer numerous benefits across environmental, economic, social, and policy domains. They interpose to mitigate climate change and to reduce GHG emissions, fostering local economic development, enhancing energy resilience and security, and promoting social cohesion and community empowerment. Additionally, RECs provide policy and regulatory advantages, facilitating the transition toward a low-carbon and resilient energy future. Despite the many benefits of RECs following the RED II directive and according to research articles and sites, there is still a large gap, showing very slow progress in many countries. Some countries show good progress by transposing the REC framework, as per RED II, while others have partially transposed the REC framework and are in the initial stage. In this paper, we focused on practical insights and scholarly trajectories to advance the research activity within this field. In particular, it has been highlighted and discussed in detail that many challenges and barriers still exist, like administrative issues, customers' unwillingness, economic and social issues, regulatory and legal challenges, policy issues, financial and funding issues from the government, grid connection barriers, like more losses, and technical issues, such as deteriorated voltage profiles and higher line loads. All these aspects could represent a barrier to REC progress and development and should be properly removed following the practical insights that were analyzed herein. Considering these challenges, the future recommendations and practical insights are listed and discussed in the next section and can lead to good results after incorporating them. Furthermore, this review paper contributes to the existing body of knowledge by providing comprehensive and up-to-date data and an analysis of RECs, which can help policymakers, researchers, industry stakeholders, and community members interested in fostering sustainable and community-driven energy systems.

7. Future Recommendations

To improve the penetration of RECs in national and local energy generation, the following future recommendation list is presented:

- Governments can introduce supportive and encouraging policies and regulations specifically for the development of RECs, including net metering, feed-in tariffs, and community-based RE targets. They should also establish clear guidelines and streamlined permitting processes to facilitate the establishment of ECs and reduce administrative hurdles. Moreover, financial support is necessary, so governments can provide tax incentives, grants, and subsidies to incentivize the formation and growth of RECs. Also, they can create dedicated funds or financial initiatives to help these RECs. These funds can provide low-interest loans, grants, or venture capital for community-led RE projects.
- Energy regulators, with government support, can update grid codes and regulations to accommodate the integration of RESs at the community level. This includes enabling two-way energy flow, putting smart grid technology into place, and making DR programs easier. It should be focused on a clear understanding and procedure to check E_c, E_g, and energy sharing, and the advantages associated with them.
- Governments and RE developers should implement community engagement strategies in the initial stages of project development, including conducting meetings to address community concerns thorough public consultations and involving local residents in decision-making processes. Conducting education and awareness campaigns can give information to communities about the gains of REs, including reduced environmental impacts, job creation, and energy cost savings.
- Not only governments but also research institutions and industry stakeholders should facilitate knowledge exchange platforms and networks for RECs, which include conferences, workshops, and other online forums where community associates can share experiences, best practices, and lessons learned. Moreover, collaboration is required among the universities, research institutions, industries, and enterprises with RECs by conducting joint research projects, providing technical assistance, and offering guidance on policy development.
- Transdisciplinary research promotional approaches are required from authorities, like governments, to bring together experts from various fields, including energy, social sciences, and policy, informing the development of effective and inclusive RE policies. Researchers can conduct comprehensive studies on the socioeconomic impacts of RECs, including job creation, local economic development, and community well-being, to provide evidence-based recommendations for policy formulation.
- It is also recommended that policymakers invest in the design of real REC systems as prototypes, making high-resolution time-dependent (for example, on an hourly basis) simulations to show for any country the economic, environmental, and social benefits to boost REC development and increase public acceptance in the community.
- Other recommendations should also be incorporated, like the adoption of legislation specifying smart meter operation; the development of tariff calculators to check and compare costs; the implementation of IT solutions closely monitored by all the stakeholders; easy-to-use tools to show all the data, including generation and consumption profiles, addresses, and meter numbers; support mechanisms dedicated to RECs; solid ICT structures and load management logistics; citizens' engagement and social acceptance awareness steps; clearly defined regulatory frameworks at regional and

national levels; increasing grid capacities; awareness campaigns for more information; easy administrative activities and access to finance in RECs; and a reduction in taxes from RECs.

By implementing these recommendations, governments, stakeholders, and communities can work together to foster the development of RECs, leading to a more decentralized, sustainable, and inclusive energy system.

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Nomenclature

ANN	artificial neural network
BESS	battery energy storage system
CEC	citizen energy community
DSO	distribution system operator
DSM	demand-side management
DR	demand response
DREs	distributed renewable energy resources
DGs	distributed generators
EES	electrical energy storage
ESS	energy storage system
EC	energy community
EMS	energy management system
EE	energy efficiency
EU	European Union
GHG	greenhouse gas
HMI	human–machine interaction
HEC	homogeneous energy community
IEC	International Electrotechnical Commission
MDT	microgrid design toolkit
MEC	mixed-energy community
PV	photovoltaic
PCM	phase change materials
PVGIS	photovoltaic geographical information system
PHS	pumped hydro storage
P2P	peer-to-peer
RE	renewable energy
REC	renewable energy community
RED II	renewable energy directive

RES	renewable energy source
REopt	renewable energy integration and optimization
RET	renewable energy technology
SEC	self-sufficient energy community
SMES	superconducting magnetic energy storage
ToU	time of use
Greek letters/Symbols/Superscripts/Subscripts	
A	effective surface area of PV plant (m^2)
D	geographical distances between members
E_g	energy generation (kWh)
E_c	energy consumption (kWh)
E_{Net}	net energy (kWh)
G	instantaneous global solar irradiance on horizontal plane (W/m^2)
i	member number
N	number of members forming REC
N_p	number of prosumers
N_c	number of consumers
n_c	PV module's efficiency
n_i	efficiency, considering balance-of-system losses from inverter, cables, etc.

References

1. Kamran, M. Current Status and Future Success of Renewable Energy in Pakistan. *Renew. Sustain. Energy Rev.* **2018**, *82*, 609–617. [CrossRef]
2. Shaikh, A.M.; Shaikh, M.F.; Shaikh, S.A.; Krichen, M.; Rahimoon, R.A.; Qadir, A. Comparative Analysis of Different MPPT Techniques Using Boost Converter for Photovoltaic Systems under Dynamic Shading Conditions. *Sustain. Energy Technol. Assess.* **2023**, *57*, 103259.
3. Materi, S.; D'Angola, A.; Enescu, D.; Renna, P. Reducing Energy Costs and CO_2 Emissions by Production System Energy Flexibility through the Integration of Renewable Energy. *Prod. Eng.* **2021**, *15*, 667–681. [CrossRef]
4. Shaikh, S.; Katyara, S.; Majeed, A.; Khand, Z.H.; Staszewski, L.; Shah, M.; Shaikh, M.F.; Bhan, V.; Memon, Q.; Majeed, U. Holistic and Scientific Perspectives of Energy Sector in Pakistan: Progression, Challenges and Opportunities. *IEEE Access* **2020**, *8*, 227232–227246. [CrossRef]
5. Gandhi, O.; Kumar, D.S.; Rodríguez-Gallegos, C.D.; Srinivasan, D. Review of Power System Impacts at High PV Penetration Part I: Factors Limiting PV Penetration. *Sol. Energy* **2020**, *210*, 181–201. [CrossRef]
6. Müller, M.; Viernstein, L.; Truong, C.N.; Eiting, A.; Hesse, H.C.; Witzmann, R.; Jossen, A. Evaluation of Grid-Level Adaptability for Stationary Battery Energy Storage System Applications in Europe. *J. Energy Storage* **2017**, *9*, 1–11. [CrossRef]
7. Sperling, K.; Hvelplund, F.; Mathiesen, B.V. Centralisation and Decentralisation in Strategic Municipal Energy Planning in Denmark. *Energy Policy* **2011**, *39*, 1338–1351. [CrossRef]
8. Gui, E.M.; MacGill, I. Typology of Future Clean Energy Communities: An Exploratory Structure, Opportunities, and Challenges. *Energy Res. Soc. Sci.* **2018**, *35*, 94–107. [CrossRef]
9. Hoffman, S.M.; Fudge, S.; Pawlisch, L.; High-Pippert, A.; Peters, M.; Haskard, J. Public Values and Community Energy: Lessons from the US and UK. *Sustainability* **2013**, *5*, 1747–1763. [CrossRef]
10. Basak, P.; Chowdhury, S.; Dey, S.H.N.; Chowdhury, S.P. A Literature Review on Integration of Distributed Energy Resources in the Perspective of Control, Protection and Stability of Microgrid. *Renew. Sustain. Energy Rev.* **2012**, *16*, 5545–5556. [CrossRef]
11. Eid, C.; Bollinger, L.A.; Koirala, B.; Scholten, D.; Facchinetti, E.; Lilliestam, J.; Hakvoort, R. Market Integration of Local Energy Systems: Is Local Energy Management Compatible with European Regulation for Retail Competition? *Energy* **2016**, *114*, 913–922. [CrossRef]
12. Kyriakopoulos, G.L. Energy Communities Overview: Managerial Policies, Economic Aspects, Technologies, and Models. *J. Risk Financ. Manag.* **2022**, *15*, 521. [CrossRef]
13. Mendes, G.; Ioakimidis, C.; Ferrão, P. On the Planning and Analysis of Integrated Community Energy Systems: A Review and Survey of Available Tools. *Renew. Sustain. Energy Rev.* **2011**, *15*, 4836–4854. [CrossRef]
14. Koirala, B.P.; Chaves Ávila, J.P.; Gómez, T.; Hakvoort, R.A.; Herder, P.M. Local Alternative for Energy Supply: Performance Assessment of Integrated Community Energy Systems. *Energies* **2016**, *9*, 981. [CrossRef]
15. European Union. Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the Promotion of the Use of Energy from Renewable Sources. *Off. J. Eur. Union* **2018**, *328*, 82–209.
16. European Union. Directive (EU) 2019/944 of 5 June 2019 on Common Rules for the Internal Market for Electricity. CHAPTER I. *Off. J. Eur. Union* **2022**, *158*, 1–67.
17. Koirala, B.P.; Koliou, E.; Friege, J.; Hakvoort, R.A.; Herder, P.M. Energetic Communities for Community Energy: A Review of Key Issues and Trends Shaping Integrated Community Energy Systems. *Renew. Sustain. Energy Rev.* **2016**, *56*, 722–744. [CrossRef]

18. Viti, S.; Lanzini, A.; Minuto, F.D.; Caldera, M.; Borchiellini, R. Techno-Economic Comparison of Buildings Acting as Single-Self Consumers or as Energy Community through Multiple Economic Scenarios. *Sustain. Cities Soc.* **2020**, *61*, 102342. [CrossRef]
19. Walker, G. What Are the Barriers and Incentives for Community-Owned Means of Energy Production and Use? *Energy Policy* **2008**, *36*, 4401–4405. [CrossRef]
20. Walker, G.; Devine-Wright, P.; Hunter, S.; High, H.; Evans, B. Trust and Community: Exploring the Meanings, Contexts and Dynamics of Community Renewable Energy. *Energy Policy* **2010**, *38*, 2655–2663. [CrossRef]
21. Rae, C.; Bradley, F. Energy Autonomy in Sustainable Communities—A Review of Key Issues. *Renew. Sustain. Energy Rev.* **2012**, *16*, 6497–6506. [CrossRef]
22. Walker, G.; Devine-Wright, P. Community Renewable Energy: What Should It Mean? *Energy Policy* **2008**, *36*, 497–500. [CrossRef]
23. Petersen, J.-P. Energy Concepts for Self-Supplying Communities Based on Local and Renewable Energy Sources: A Case Study from Northern Germany. *Sustain. Cities Soc.* **2016**, *26*, 1–8. [CrossRef]
24. Iliopoulos, T.G. The Promotion of Renewable Energy Communities in the European Union. In *Energy Services Fundamentals and Financing*; Elsevier: Amsterdam, The Netherlands, 2021; pp. 37–53.
25. Uyar, T.S.; Beşikci, D. Integration of Hydrogen Energy Systems into Renewable Energy Systems for Better Design of 100% Renewable Energy Communities. *Int. J. Hydrogen Energy* **2017**, *42*, 2453–2456. [CrossRef]
26. Friman, H.; Banner, I.; Sitbon, Y.; Einav, Y.; Shaked, N. Preparing the Public Opinion in the Community to Accept Distributed Energy Systems and Renewable Energy. *Energies* **2022**, *15*, 4226. [CrossRef]
27. Belmar, F.; Baptista, P.; Neves, D. Modelling Renewable Energy Communities: Assessing the Impact of Different Configurations, Technologies and Types of Participants. *Energy Sustain. Soc.* **2023**, *13*, 1–25.
28. Azarova, V.; Cohen, J.; Friedl, C.; Reichl, J. Designing Local Renewable Energy Communities to Increase Social Acceptance: Evidence from a Choice Experiment in Austria, Germany, Italy, and Switzerland. *Energy Policy* **2019**, *132*, 1176–1183. [CrossRef]
29. Zhou, Y.; Lund, P.D. Peer-to-Peer Energy Sharing and Trading of Renewable Energy in Smart Communities—Trading Pricing Models, Decision-Making and Agent-Based Collaboration. *Renew. Energy* **2023**, *207*, 177–193. [CrossRef]
30. Sousa, J.; Lagarto, J.; Camus, C.; Viveiros, C.; Barata, F.; Silva, P.; Alegria, R.; Paraíba, O. Renewable Energy Communities Optimal Design Supported by an Optimization Model for Investment in PV/Wind Capacity and Renewable Electricity Sharing. *Energy* **2023**, *283*, 128464. [CrossRef]
31. Li, N.; Okur, Ö. Economic Analysis of Energy Communities: Investment Options and Cost Allocation. *Appl. Energy* **2023**, *336*, 120706. [CrossRef]
32. Casalicchio, V.; Manzolini, G.; Prina, M.G.; Moser, D. From Investment Optimization to Fair Benefit Distribution in Renewable Energy Community Modelling. *Appl. Energy* **2022**, *310*, 118447. [CrossRef]
33. Hoicka, C.E.; Lowitzsch, J.; Brisbois, M.C.; Kumar, A.; Camargo, L.R. Implementing a Just Renewable Energy Transition: Policy Advice for Transposing the New European Rules for Renewable Energy Communities. *Energy Policy* **2021**, *156*, 112435. [CrossRef]
34. D'Alpaos, C.; Andreolli, F. Renewable Energy Communities: The Challenge for New Policy and Regulatory Frameworks Design. In *New Metropolitan Perspectives: Knowledge Dynamics and Innovation-Driven Policies Towards Urban and Regional Transition*; Springer: Berlin/Heidelberg, Germany, 2021; Volume 2, pp. 500–509.
35. Lazdins, R.; Mutule, A.; Zalostiba, D. PV Energy Communities—Challenges and Barriers from a Consumer Perspective: A Literature Review. *Energies* **2021**, *14*, 4873. [CrossRef]
36. Sokolowski, M.M. Renewable Energy Communities in the Law of the EU, Australia, and New Zealand. *Eur. Energy Environ. Law Rev.* **2019**, *28*, 34–46. [CrossRef]
37. Romero-Rubio, C.; de Andrés Díaz, J.R. Sustainable Energy Communities: A Study Contrasting Spain and Germany. *Energy Policy* **2015**, *85*, 397–409. [CrossRef]
38. Cielo, A.; Margiaria, P.; Lazzeroni, P.; Mariuzzo, I.; Repetto, M. Renewable Energy Communities Business Models under the 2020 Italian Regulation. *J. Clean. Prod.* **2021**, *316*, 128217. [CrossRef]
39. Casalicchio, V.; Manzolini, G.; Prina, M.G.; Moser, D. Renewable Energy Communities: Business Models of Multi-Family Housing Buildings. In *Smart and Sustainable Planning for Cities and Region. Results of SSPCR 2019*; Springer: Cham, Switzerland, 2021; pp. 261–276.
40. Hahnel, U.J.J.; Herberz, M.; Pena-Bello, A.; Parra, D.; Brosch, T. Becoming Prosumer: Revealing Trading Preferences and Decision-Making Strategies in Peer-to-Peer Energy Communities. *Energy Policy* **2020**, *137*, 111098. [CrossRef]
41. Kracher, A. Renewable Energy Communities—Exploring Behavioral and Motivational Factors behind the Willingness to Participate in Renewable Energy Communities in Germany. Master's Thesis, Lund University, Lund, Sweden, May 2021.
42. Grève, Z.; De Bottieau, J.; Vangulick, D.; Wautier, A.; Dapoz, P.-D.; Arrigo, A.; Toubeau, J.-F.; Vallée, F. Machine Learning Techniques for Improving Self-Consumption in Renewable Energy Communities. *Energies* **2020**, *13*, 4892. [CrossRef]
43. Bashi, M.H.; De Tommasi, L.; Le Cam, A.; Relaño, L.S.; Lyons, P.; Mundó, J.; Pandelieva-Dimova, I.; Schapp, H.; Loth-Babut, K.; Egger, C. A Review and Mapping Exercise of Energy Community Regulatory Challenges in European Member States Based on a Survey of Collective Energy Actors. *Renew. Sustain. Energy Rev.* **2023**, *172*, 113055. [CrossRef]
44. Kallis, G.; Stephanides, P.; Bailey, E.; Devine-Wright, P.; Chalvatzis, K.; Bailey, I. The Challenges of Engaging Island Communities: Lessons on Renewable Energy from a Review of 17 Case Studies. *Energy Res. Soc. Sci.* **2021**, *81*, 102257. [CrossRef]
45. Kubli, M.; Puranik, S. A Typology of Business Models for Energy Communities: Current and Emerging Design Options. *Renew. Sustain. Energy Rev.* **2023**, *176*, 113165. [CrossRef]

46. Kazmi, H.; Munné-Collado, Í.; Mehmood, F.; Syed, T.A.; Driesen, J. Towards Data-Driven Energy Communities: A Review of Open-Source Datasets, Models and Tools. *Renew. Sustain. Energy Rev.* **2021**, *148*, 111290. [CrossRef]
47. Tatti, A.; Ferroni, S.; Ferrando, M.; Motta, M.; Causone, F. The Emerging Trends of Renewable Energy Communities' Development in Italy. *Sustainability* **2023**, *15*, 6792. [CrossRef]
48. Heldeweg, M.A.; Saintier, S. Renewable Energy Communities as 'Socio-Legal Institutions': A Normative Frame for Energy Decentralization? *Renew. Sustain. Energy Rev.* **2020**, *119*, 109518. [CrossRef]
49. Gjorgievski, V.Z.; Cundeva, S.; Georghiou, G.E. Social Arrangements, Technical Designs and Impacts of Energy Communities: A Review. *Renew. Energy* **2021**, *169*, 1138–1156. [CrossRef]
50. Inês, C.; Guilherme, P.L.; Esther, M.-G.; Swantje, G.; Stephen, H.; Lars, H. Regulatory Challenges and Opportunities for Collective Renewable Energy Prosumers in the EU. *Energy Policy* **2020**, *138*, 111212. [CrossRef]
51. Lode, M.L.; Te Boveldt, G.; Coosemans, T.; Camargo, L.R. A Transition Perspective on Energy Communities: A Systematic Literature Review and Research Agenda. *Renew. Sustain. Energy Rev.* **2022**, *163*, 112479. [CrossRef]
52. Reis, I.F.G.; Gonçalves, I.; Lopes, M.A.R.; Antunes, C.H. Business Models for Energy Communities: A Review of Key Issues and Trends. *Renew. Sustain. Energy Rev.* **2021**, *144*, 111013. [CrossRef]
53. Hewitt, R.J.; Bradley, N.; Baggio Compagnucci, A.; Barlagne, C.; Ceglarz, A.; Cremades, R.; McKeen, M.; Otto, I.M.; Slee, B. Social Innovation in Community Energy in Europe: A Review of the Evidence. *Front. Energy Res.* **2019**, *7*, 31. [CrossRef]
54. Hanke, F.; Guyet, R.; Feenstra, M. Do Renewable Energy Communities Deliver Energy Justice? Exploring Insights from 71 European Cases. *Energy Res. Soc. Sci.* **2021**, *80*, 102244. [CrossRef]
55. Dóci, G.; Vasileiadou, E.; Petersen, A.C. Exploring the Transition Potential of Renewable Energy Communities. *Futures* **2015**, *66*, 85–95. [CrossRef]
56. Krug, M.; Di Nucci, M.R.; Caldera, M.; De Luca, E. Mainstreaming Community Energy: Is the Renewable Energy Directive a Driver for Renewable Energy Communities in Germany and Italy? *Sustainability* **2022**, *14*, 7181. [CrossRef]
57. Huang, Z.; Yu, H.; Peng, Z.; Feng, Y. Planning Community Energy System in the Industry 4.0 Era: Achievements, Challenges and a Potential Solution. *Renew. Sustain. Energy Rev.* **2017**, *78*, 710–721. [CrossRef]
58. Kooij, H.-J.; Oteman, M.; Veenman, S.; Sperling, K.; Magnusson, D.; Palm, J.; Hvelplund, F. Between Grassroots and Treetops: Community Power and Institutional Dependence in the Renewable Energy Sector in Denmark, Sweden and the Netherlands. *Energy Res. Soc. Sci.* **2018**, *37*, 52–64. [CrossRef]
59. Warbroek, B.; Hoppe, T.; Bressers, H.; Coenen, F. Testing the Social, Organizational, and Governance Factors for Success in Local Low Carbon Energy Initiatives. *Energy Res. Soc. Sci.* **2019**, *58*, 101269. [CrossRef]
60. Heiskanen, E.; Johnson, M.; Robinson, S.; Vadovics, E.; Saastamoinen, M. Low-Carbon Communities as a Context for Individual Behavioural Change. *Energy Policy* **2010**, *38*, 7586–7595. [CrossRef]
61. The European Parliament and The Council of The European Union. 2019/944 on Common Rules for the Internal Market for Electricity and Amending Directive 2012/27/EU. *Off. J. Eur. Union* **2019**, *158*, 125–199.
62. Blasch, J.; van der Grijp, N.M.; Petrovics, D.; Palm, J.; Bocken, N.; Darby, S.J.; Barnes, J.; Hansen, P.; Kamin, T.; Golob, U. New Clean Energy Communities in Polycentric Settings: Four Avenues for Future Research. *Energy Res. Soc. Sci.* **2021**, *82*, 102276. [CrossRef]
63. Tricarico, L. Is Community Earning Enough? Reflections on Engagement Processes and Drivers in Two Italian Energy Communities. *Energy Res. Soc. Sci.* **2021**, *72*, 101899. [CrossRef]
64. Canizes, B.; Costa, J.; Bairrão, D.; Vale, Z. Local Renewable Energy Communities: Classification and Sizing. *Energies* **2023**, *16*, 2389. [CrossRef]
65. Roberts, J.; Frieden, D.; D'Herbemont, S. *COMPILE Project—Energy Community Definitions*; Compile: Graz, Austria, 2019.
66. Energy Communities. Available online: https://energy.ec.europa.eu/topics/markets-and-consumers/energy-communities_en (accessed on 14 July 2023).
67. Ceglia, F.; Esposito, P.; Marrasso, E.; Sasso, M. From Smart Energy Community to Smart Energy Municipalities: Literature Review, Agendas and Pathways. *J. Clean. Prod.* **2020**, *254*, 120118. [CrossRef]
68. Chaudhry, S.; Surmann, A.; Kühnbach, M.; Pierie, F. Renewable Energy Communities as Modes of Collective Prosumership: A Multi-Disciplinary Assessment Part II—Case Study. *Energies* **2022**, *15*, 8936. [CrossRef]
69. McKenna, R. The Double-Edged Sword of Decentralized Energy Autonomy. *Energy Policy* **2018**, *113*, 747–750. [CrossRef]
70. D'Angola, A.; Zaffina, R.; Enescu, D.; Di Leo, P.; Fracastoro, G.V.; Spertino, F. Best Compromise of Net Power Gain in a Cooled Photovoltaic System. In Proceedings of the 2016 51st International Universities Power Engineering Conference (UPEC), Coimbra, Portugal, 6–9 September 2016; IEEE: New York, NY, USA, 2016; pp. 1–6.
71. D'Angola, A.; Enescu, D.; Mecca, M.; Ciocia, A.; Leo, P.; Di Fracastoro, G.V.; Spertino, F. Theoretical and Numerical Study of a Photovoltaic System with Active Fluid Cooling by a Fully-Coupled 3D Thermal and Electric Model. *Energies* **2020**, *13*, 852. [CrossRef]
72. Gruber, L.; Bachhiesl, U.; Wogrin, S. The Current State of Research on Energy Communities. *e & i Elektrotechnik und Informationstechnik* **2021**, *138*, 515–524.
73. Yiasoumas, G.; Psara, K.; Georghiou, G.E. A Review of Energy Communities: Definitions, Technologies, Data Management. In Proceedings of the 2022 2nd International Conference on Energy Transition in the Mediterranean Area (SyNERGY MED), Thessaloniki, Greece, 17–19 October 2022; IEEE: New York, NY, USA, 2022; pp. 1–6.

74. Warbroek, B.; Hoppe, T.; Coenen, F.; Bressers, H. The Role of Intermediaries in Supporting Local Low-Carbon Energy Initiatives. *Sustainability* **2018**, *10*, 2450. [CrossRef]
75. Weckesser, T.; Dominković, D.F.; Blomgren, E.M.V.; Schledorn, A.; Madsen, H. Renewable Energy Communities: Optimal Sizing and Distribution Grid Impact of Photo-Voltaics and Battery Storage. *Appl. Energy* **2021**, *301*, 117408. [CrossRef]
76. Seyfang, G.; Park, J.J.; Smith, A. A Thousand Flowers Blooming? An Examination of Community Energy in the UK. *Energy Policy* **2013**, *61*, 977–989. [CrossRef]
77. Van Der Schoor, T.; Scholtens, B. Power to the People: Local Community Initiatives and the Transition to Sustainable Energy. *Renew. Sustain. Energy Rev.* **2015**, *43*, 666–675. [CrossRef]
78. Becker, S.; Kunze, C.; Vancea, M. Community Energy and Social Entrepreneurship: Addressing Purpose, Organisation and Embeddedness of Renewable Energy Projects. *J. Clean. Prod.* **2017**, *147*, 25–36. [CrossRef]
79. Bauwens, T. Propriété Coopérative et Acceptabilité Sociale de l'éolien Terrestre. *Reflets Perspect. Économique* **2015**, *54*, 59–70. [CrossRef]
80. Ruggiero, S.; Busch, H.; Hansen, T.; Isakovic, A. Context and Agency in Urban Community Energy Initiatives: An Analysis of Six Case Studies from the Baltic Sea Region. *Energy Policy* **2021**, *148*, 111956. [CrossRef]
81. Wirth, S. Communities Matter: Institutional Preconditions for Community Renewable Energy. *Energy Policy* **2014**, *70*, 236–246. [CrossRef]
82. Walker, G.; Simcock, N.; Smith, S.J. Community Energy Systems. *Int. Encycl. Hous. Home* **2012**, *1*, 2019.
83. Huijben, J.C.C.M.; Verbong, G.P.J. Breakthrough without Subsidies? PV Business Model Experiments in the Netherlands. *Energy Policy* **2013**, *56*, 362–370. [CrossRef]
84. Energy Communities in Italy and in Europe | Enel Green Power. Available online: https://www.enelgreenpower.com/countries/europe/Italy/renewable-energy-communities/renewable-energy-communities-italy-europe (accessed on 9 August 2023).
85. Hoffman, S.M.; High-Pippert, A. From Private Lives to Collective Action: Recruitment and Participation Incentives for a Community Energy Program. *Energy Policy* **2010**, *38*, 7567–7574. [CrossRef]
86. Davis, P.; Worthington, S. Cooperative Values: Change and Continuity in Capital Accumulation the Case of the British Cooperative Bank. *J. Bus. Ethics* **1993**, *12*, 849–859. [CrossRef]
87. Koutra, S.; Pagnoule, C.; Galatoulas, N.-F.; Bagheri, A.; Waroux, T.; Becue, V.; Ioakimidis, C.S. The Zero-Energy Idea in Districts: Application of a Methodological Approach to a Case Study of Epinlieu (Mons). *Sustainability* **2019**, *11*, 4814. [CrossRef]
88. Koch, A.; Girard, S.; McKoen, K. Towards a Neighbourhood Scale for Low-or Zero-Carbon Building Projects. *Build. Res. Inf.* **2012**, *40*, 527–537. [CrossRef]
89. Mittal, A.; Krejci, C.C.; Dorneich, M.C.; Fickes, D. An Agent-Based Approach to Modeling Zero Energy Communities. *Sol. Energy* **2019**, *191*, 193–204. [CrossRef]
90. Mavrigiannaki, A.; Gobakis, K.; Kolokotsa, D.; Kalaitzakis, K.; Pisello, A.L.; Piselli, C.; Laskari, M.; Saliari, M.; Assimakopoulos, M.-N.; Pignatta, G. Zero Energy Concept at Neighborhood Level: A Case Study Analysis. *Sol. Energy Adv.* **2021**, *1*, 100002. [CrossRef]
91. WWF. *Repowering EU Coal Regions Municipality-Led Renewable Energy Projects*; WWF: Washington, DC, USA, 2022.
92. Gerundo, R.; Marra, A. A Decision Support Methodology to Foster Renewable Energy Communities in the Municipal Urban Plan. *Sustainability* **2022**, *14*, 16268. [CrossRef]
93. Pandyaswargo, A.H.; Wibowo, A.D.; Onoda, H. Socio-Techno-Economic Assessment to Design an Appropriate Renewable Energy System for Remote Agricultural Communities in Developing Countries. *Sustain. Prod. Consum.* **2022**, *31*, 492–511. [CrossRef]
94. Kaygusuz, K. Energy Services and Energy Poverty for Sustainable Rural Development. *Renew. Sustain. Energy Rev.* **2011**, *15*, 936–947. [CrossRef]
95. Biswas, W.K.; Bryce, P.; Diesendorf, M. Model for Empowering Rural Poor through Renewable Energy Technologies in Bangladesh. *Environ. Sci. Policy* **2001**, *4*, 333–344. [CrossRef]
96. Stefanelli, R.D.; Walker, C.; Kornelsen, D.; Lewis, D.; Martin, D.H.; Masuda, J.; Richmond, C.A.M.; Root, E.; Tait Neufeld, H.; Castleden, H. Renewable Energy and Energy Autonomy: How Indigenous Peoples in Canada Are Shaping an Energy Future. *Environ. Rev.* **2019**, *27*, 95–105. [CrossRef]
97. Calise, F.; Duic, N.; Pfeifer, A.; Vicidomini, M.; Orlando, A.M. Moving the System Boundaries in Decarbonization of Large Islands. *Energy Convers. Manag.* **2021**, *234*, 113956. [CrossRef]
98. Kyriakarakos, G.; Papadakis, G.; Karavitis, C.A. Renewable Energy Desalination for Island Communities: Status and Future Prospects in Greece. *Sustainability* **2022**, *14*, 8176. [CrossRef]
99. Corsini, A.; Delibra, G.; Pizzuti, I.; Tajalli-Ardekani, E. Challenges of Renewable Energy Communities on Small Mediterranean Islands: A Case Study on Ponza Island. *Renew. Energy* **2023**, *215*, 118986. [CrossRef]
100. Groppi, D.; Pfeifer, A.; Garcia, D.A.; Krajačić, G.; Duić, N. A Review on Energy Storage and Demand Side Management Solutions in Smart Energy Islands. *Renew. Sustain. Energy Rev.* **2021**, *135*, 110183. [CrossRef]
101. Dorotić, H.; Doračić, B.; Dobravec, V.; Pukšec, T.; Krajačić, G.; Duić, N. Integration of Transport and Energy Sectors in Island Communities with 100% Intermittent Renewable Energy Sources. *Renew. Sustain. Energy Rev.* **2019**, *99*, 109–124. [CrossRef]
102. Martiskainen, M. The Role of Community Leadership in the Development of Grassroots Innovations. *Environ. Innov. Soc. Transit.* **2017**, *22*, 78–89. [CrossRef]

103. Cloke, J.; Mohr, A.; Brown, E. Imagining Renewable Energy: Towards a Social Energy Systems Approach to Community Renewable Energy Projects in the Global South. *Energy Res. Soc. Sci.* **2017**, *31*, 263–272. [CrossRef]
104. Ceglia, F.; Esposito, P.; Sasso, M. Smart Energy Community and Collective Awareness: A Systematic Scientific and Normative Review. In Proceedings of the 12th Annual Conference of the EuroMed Academy of Business, Thessaloniki, Greece, 18–20 September 2019.
105. Sæle, H.; Morch, A.; Buonanno, A.; Caliano, M.; Di Somma, M.; Papadimitriou, C. Development of Energy Communities in Europe. In Proceedings of the 2022 18th International Conference on the European Energy Market (EEM), Ljubljana, Slovenia, 13–15 September 2022; IEEE: New York, NY, USA, 2022; pp. 1–5.
106. Brummer, V. Community Energy–Benefits and Barriers: A Comparative Literature Review of Community Energy in the UK, Germany and the USA, the Benefits It Provides for Society and the Barriers It Faces. *Renew. Sustain. Energy Rev.* **2018**, *94*, 187–196. [CrossRef]
107. Islar, M.; Busch, H. "We Are Not in This to Save the Polar Bears!"—The Link between Community Renewable Energy Development and Ecological Citizenship. *Innov. Eur. J. Soc. Sci. Res.* **2016**, *29*, 303–319. [CrossRef]
108. Akizu, O.; Bueno, G.; Barcena, I.; Kurt, E.; Topaloğlu, N.; Lopez-Guede, J.M. Contributions of Bottom-up Energy Transitions in Germany: A Case Study Analysis. *Energies* **2018**, *11*, 849. [CrossRef]
109. Gui, E.M.; Diesendorf, M.; MacGill, I. Distributed Energy Infrastructure Paradigm: Community Microgrids in a New Institutional Economics Context. *Renew. Sustain. Energy Rev.* **2017**, *72*, 1355–1365. [CrossRef]
110. Young, J.; Brans, M. Analysis of Factors Affecting a Shift in a Local Energy System towards 100% Renewable Energy Community. *J. Clean. Prod.* **2017**, *169*, 117–124. [CrossRef]
111. Warbroek, B.; Hoppe, T. Modes of Governing and Policy of Local and Regional Governments Supporting Local Low-Carbon Energy Initiatives; Exploring the Cases of the Dutch Regions of Overijssel and Fryslân. *Sustainability* **2017**, *9*, 75. [CrossRef]
112. Moroni, S.; Antoniucci, V.; Bisello, A. Energy Sprawl, Land Taking and Distributed Generation: Towards a Multi-Layered Density. *Energy Policy* **2016**, *98*, 266–273. [CrossRef]
113. Damato, A.; Iamarino, M.; Ferraro, A.; D'Angola, A. PV-Based Hybrid Residential Microgrid with Hydrogen and Battery Energy Storage Options: A Northern Italy Case Study. *J. Phys. Conf. Ser.* **2022**, *2385*, 12119. [CrossRef]
114. Creamer, E.; Eadson, W.; van Veelen, B.; Pinker, A.; Tingey, M.; Braunholtz-Speight, T.; Markantoni, M.; Foden, M.; Lacey-Barnacle, M. Community Energy: Entanglements of Community, State, and Private Sector. *Geogr. Compass* **2018**, *12*, e12378. [CrossRef]
115. Rogers, J.C.; Simmons, E.A.; Convery, I.; Weatherall, A. Social Impacts of Community Renewable Energy Projects: Findings from a Woodfuel Case Study. *Energy Policy* **2012**, *42*, 239–247. [CrossRef]
116. Vihalemm, T.; Keller, M. Consumers, Citizens or Citizen-Consumers? Domestic Users in the Process of Estonian Electricity Market Liberalization. *Energy Res. Soc. Sci.* **2016**, *13*, 38–48. [CrossRef]
117. Saunders, R.W.; Gross, R.J.K.; Wade, J. Can Premium Tariffs for Micro-Generation and Small Scale Renewable Heat Help the Fuel Poor, and If so, How? Case Studies of Innovative Finance for Community Energy Schemes in the UK. *Energy Policy* **2012**, *42*, 78–88. [CrossRef]
118. Seyfang, G.; Smith, A. Grassroots Innovations for Sustainable Development: Towards a New Research and Policy Agenda. *Environ. Polit.* **2007**, *16*, 584–603. [CrossRef]
119. Ruggiero, S.; Martiskainen, M.; Onkila, T. Understanding the Scaling-up of Community Energy Niches through Strategic Niche Management Theory: Insights from Finland. *J. Clean. Prod.* **2018**, *170*, 581–590. [CrossRef]
120. Caramizaru, A.; Uihlein, A. *Energy Communities: An Overview of Energy and Social Innovation Social Aspects of the Energy Transition*; Publications Office of the European Union: Luxembourg, 2020; ISBN 9789276107132.
121. Boon, F.P.; Dieperink, C. Local Civil Society Based Renewable Energy Organisations in the Netherlands: Exploring the Factors That Stimulate Their Emergence and Development. *Energy Policy* **2014**, *69*, 297–307. [CrossRef]
122. Franco, J.F.; Macedo, L.H.; Arias, N.B.; Tabares, A.; Romero, R.; Soares, J. Mathematical Models and Optimization Techniques to Support Local Electricity Markets. In *Local Electricity Markets*; Elsevier: Amsterdam, The Netherlands, 2021; pp. 259–276.
123. Atwa, Y.M.; El-Saadany, E.F.; Salama, M.M.A.; Seethapathy, R. Optimal Renewable Resources Mix for Distribution System Energy Loss Minimization. *IEEE Trans. Power Syst.* **2009**, *25*, 360–370. [CrossRef]
124. Tang, J.; Ni, H.; Peng, R.-L.; Wang, N.; Zuo, L. A Review on Energy Conversion Using Hybrid Photovoltaic and Thermoelectric Systems. *J. Power Sources* **2023**, *562*, 232785. [CrossRef]
125. Von Wirth, T.; Gislason, L.; Seidl, R. Distributed Energy Systems on a Neighborhood Scale: Reviewing Drivers of and Barriers to Social Acceptance. *Renew. Sustain. Energy Rev.* **2018**, *82*, 2618–2628. [CrossRef]
126. Shaikh, S.A.; Shaikh, A.M.; Shaikh, M.F.; Jiskani, S.A.; Memon, Q.A. Technical and Economical Evaluation of Solar PV System for Domestic Load in Pakistan: An Overlook Contributor to High Tariff and Load Shedding. *Sir Syed Univ. Res. J. Eng. Technol.* **2022**, *12*, 23–30. [CrossRef]
127. Paliwal, P.; Patidar, N.P.; Nema, R.K. Planning of Grid Integrated Distributed Generators: A Review of Technology, Objectives and Techniques. *Renew. Sustain. Energy Rev.* **2014**, *40*, 557–570. [CrossRef]
128. EUR-Lex—32019L0944—EN—EUR-Lex. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32019L0944 (accessed on 14 July 2023).
129. Fina, B.; Auer, H. Economic Viability of Renewable Energy Communities under the Framework of the Renewable Energy Directive Transposed to Austrian Law. *Energies* **2020**, *13*, 5743. [CrossRef]

130. Widén, J.; Wäckelgård, E.; Paatero, J.; Lund, P. Impacts of Distributed Photovoltaics on Network Voltages: Stochastic Simulations of Three Swedish Low-Voltage Distribution Grids. *Electr. Power Syst. Res.* **2010**, *80*, 1562–1571. [CrossRef]
131. Bauwens, T.; Gotchev, B.; Holstenkamp, L. What Drives the Development of Community Energy in Europe? The Case of Wind Power Cooperatives. *Energy Res. Soc. Sci.* **2016**, *13*, 136–147. [CrossRef]
132. Michas, S.; Stavrakas, V.; Spyridaki, N.-A.; Flamos, A. Identifying Research Priorities for the Further Development and Deployment of Solar Photovoltaics. *Int. J. Sustain. Energy* **2019**, *38*, 276–296. [CrossRef]
133. Vuddanti, S.; Salkuti, S.R. Review of Energy Management System Approaches in Microgrids. *Energies* **2021**, *14*, 5459.
134. Viral, R.; Khatod, D.K. Optimal Planning of Distributed Generation Systems in Distribution System: A Review. *Renew. Sustain. Energy Rev.* **2012**, *16*, 5146–5165. [CrossRef]
135. Somefun, T.; Popoola, O.; Abdulkareem, A.; Awelewa, A. Review of Different Methods for Siting and Sizing Distributed Generator. *Int. J. Energy Econ. Policy* **2022**, *12*, 16. [CrossRef]
136. Ford, R.; Whitaker, J.; Stephenson, J. *Prosumer Collectives: A Review*; University of Otago: Dunedin, New Zealand, 2016.
137. Brand, L.; Calvén, A.; Englund, J.; Landersjö, H.; Lauenburg, P. Smart District Heating Networks–A Simulation Study of Prosumers' Impact on Technical Parameters in Distribution Networks. *Appl. Energy* **2014**, *129*, 39–48. [CrossRef]
138. Da Silva, P.G.; Ilić, D.; Karnouskos, S. The Impact of Smart Grid Prosumer Grouping on Forecasting Accuracy and Its Benefits for Local Electricity Market Trading. *IEEE Trans. Smart Grid* **2013**, *5*, 402–410. [CrossRef]
139. Kästel, P.; Gilroy-Scott, B. Economics of Pooling Small Local Electricity Prosumers—LCOE & Self-Consumption. *Renew. Sustain. Energy Rev.* **2015**, *51*, 718–729.
140. Kotilainen, K. *Perspectives on the Prosumer Role in the Sustainable Energy System*; Tampere University: Tampere, Finland, 2020; ISBN 9520315764.
141. Algarvio, H. The Role of Local Citizen Energy Communities in the Road to Carbon-Neutral Power Systems: Outcomes from a Case Study in Portugal. *Smart Cities* **2021**, *4*, 840–863. [CrossRef]
142. Alifia, T.; Fraser, K. Achieving Renewable Energy Targets: The Impact of Residential Solar PV Prosumers in Indonesia. *Int. J. Sustain. Energy Plan. Manag.* **2021**, *32*, 111–124.
143. Masson, G.; Orlandi, S.; Petrick, K.; Cassagne, V.; Briano, J.I.; Morandi, M.J.B.; Margolis, R.; Rickerson, W. PV Development as Prosumers: The Role and Challenges Associated to Producing and Selfconsuming PV Electricity. In Proceedings of the 4th International Workshop on Integration of Solar Power into Power Systems, Berlin, Germany, 10–11 November 2014.
144. Rathnayaka, A.J.D.; Potdar, V.M.; Dillon, T.S.; Hussain, O.K.; Chang, E. A Methodology to Find Influential Prosumers in Prosumer Community Groups. *IEEE Trans. Ind. Inform.* **2013**, *10*, 706–713. [CrossRef]
145. Yildiz, Ö.; Gotchev, B.; Holstenkamp, L.; Müller, J.R.; Radtke, J.; Welle, L. Consumer (Co-) Ownership in Renewables in Germany. In *Energy Transition: Financing Consumer Co-Ownership in Renewables*; S&P Global: New York, NY, USA, 2019; pp. 271–293.
146. Lowitzsch, J.; Hoicka, C.E.; van Tulder, F.J. Renewable Energy Communities under the 2019 European Clean Energy Package–Governance Model for the Energy Clusters of the Future? *Renew. Sustain. Energy Rev.* **2020**, *122*, 109489. [CrossRef]
147. Ibrahim, H.; Ilinca, A.; Perron, J. Energy Storage Systems—Characteristics and Comparisons. *Renew. Sustain. Energy Rev.* **2008**, *12*, 1221–1250. [CrossRef]
148. Ibrahim, H.; Beguenane, R.; Merabet, A. Technical and Financial Benefits of Electrical Energy Storage. In Proceedings of the 2012 IEEE Electrical Power and Energy Conference, Kota Kinabalu, Malaysia, 2–5 December 2012; IEEE: New York, NY, USA, 2012; pp. 86–91.
149. Mitali, J.; Dhinakaran, S.; Mohamad, A.A. Energy Storage Systems: A Review. *Energy Storage Sav.* **2022**, *1*, 166–216. [CrossRef]
150. Das, C.K.; Bass, O.; Kothapalli, G.; Mahmoud, T.S.; Habibi, D. Overview of Energy Storage Systems in Distribution Networks: Placement, Sizing, Operation, and Power Quality. *Renew. Sustain. Energy Rev.* **2018**, *91*, 1205–1230. [CrossRef]
151. Masaud, T.M.; Lee, K.; Sen, P.K. An Overview of Energy Storage Technologies in Electric Power Systems: What Is the Future? In Proceedings of the North American Power Symposium, Arlington, TX, USA, 26–28 September 2010; IEEE: New York, NY, USA, 2010; pp. 1–6.
152. Schoenung, S.M.; Eyer, J.M.; Iannucci, J.J.; Horgan, S.A. Energy Storage for a Competitive Power Market. *Annu. Rev. Energy Environ.* **1996**, *21*, 347–370. [CrossRef]
153. Chen, H.; Cong, T.N.; Yang, W.; Tan, C.; Li, Y.; Ding, Y. Progress in Electrical Energy Storage System: A Critical Review. *Prog. Nat. Sci.* **2009**, *19*, 291–312. [CrossRef]
154. Hannan, M.A.; Wali, S.B.; Ker, P.J.; Abd Rahman, M.S.; Mansor, M.; Ramachandaramurthy, V.K.; Muttaqi, K.M.; Mahlia, T.M.I.; Dong, Z.Y. Battery Energy-Storage System: A Review of Technologies, Optimization Objectives, Constraints, Approaches, and Outstanding Issues. *J. Energy Storage* **2021**, *42*, 103023. [CrossRef]
155. Herenčić, L.; Kirac, M.; Keko, H.; Kuzle, I.; Rajšl, I. Automated Energy Sharing in MV and LV Distribution Grids within an Energy Community: A Case for Croatian City of Križevci with a Hybrid Renewable System. *Renew. Energy* **2022**, *191*, 176–194. [CrossRef]
156. Ruparathna, R.; Hewage, K.; Karunathilake, H.; Dyck, R.; Idris, A.; Culver, K.; Sadiq, R. Climate Conscious Regional Planning for Fast-Growing Communities. *J. Clean. Prod.* **2017**, *165*, 81–92. [CrossRef]
157. Mehrjerdi, H. Peer-to-Peer Home Energy Management Incorporating Hydrogen Storage System and Solar Generating Units. *Renew. Energy* **2020**, *156*, 183–192. [CrossRef]
158. Duvignau, R.; Heinisch, V.; Göransson, L.; Gulisano, V.; Papatriantafilou, M. Benefits of Small-Size Communities for Continuous Cost-Optimization in Peer-to-Peer Energy Sharing. *Appl. Energy* **2021**, *301*, 117402. [CrossRef]

159. JRC Photovoltaic Geographical Information System (PVGIS)—European Commission. Available online: https://re.jrc.ec.europa.eu/pvg_tools/en/ (accessed on 25 December 2023).
160. Gjorgievski, V.Z.; Velkovski, B.; Minuto, F.D.; Cundeva, S.; Markovska, N. Energy Sharing in European Renewable Energy Communities: Impact of Regulated Charges. *Energy* **2023**, *281*, 128333. [CrossRef]
161. Radl, J.; Fleischhacker, A.; Revheim, F.H.; Lettner, G.; Auer, H. Comparison of Profitability of PV Electricity Sharing in Renewable Energy Communities in Selected European Countries. *Energies* **2020**, *13*, 5007. [CrossRef]
162. Di Lorenzo, G.; Rotondo, S.; Araneo, R.; Petrone, G.; Martirano, L. Innovative Power-Sharing Model for Buildings and Energy Communities. *Renew. Energy* **2021**, *172*, 1087–1102. [CrossRef]
163. Martirano, L.; Rotondo, S.; Kermani, M.; Massarella, F.; Gravina, R. Power Sharing Model for Energy Communities of Buildings. *IEEE Trans. Ind. Appl.* **2020**, *57*, 170–178. [CrossRef]
164. Fina, B.; Auer, H.; Friedl, W. Profitability of PV Sharing in Energy Communities: Use Cases for Different Settlement Patterns. *Energy* **2019**, *189*, 116148. [CrossRef]
165. Ceglia, F.; Marrasso, E.; Pallotta, G.; Roselli, C.; Sasso, M. The State of the Art of Smart Energy Communities: A Systematic Review of Strengths and Limits. *Energies* **2022**, *15*, 3462. [CrossRef]
166. Ceglia, F.; Esposito, P.; Faraudello, A.; Marrasso, E.; Rossi, P.; Sasso, M. An Energy, Environmental, Management and Economic Analysis of Energy Efficient System towards Renewable Energy Community: The Case Study of Multi-Purpose Energy Community. *J. Clean. Prod.* **2022**, *369*, 133269. [CrossRef]
167. Vega, S.H.; van Leeuwen, E.; van Twillert, N. Uptake of Residential Energy Efficiency Measures and Renewable Energy: Do Spatial Factors Matter? *Energy Policy* **2022**, *160*, 112659. [CrossRef]
168. Vine, E.; Mills, E.; Chen, A. Energy-Efficiency and Renewable Energy Options for Risk Management and Insurance Loss Reduction. *Energy* **2000**, *25*, 131–147. [CrossRef]
169. Nejat, P.; Jomehzadeh, F.; Taheri, M.M.; Gohari, M.; Majid, M.Z.A. A Global Review of Energy Consumption, CO_2 Emissions and Policy in the Residential Sector (with an Overview of the Top Ten CO_2 Emitting Countries). *Renew. Sustain. Energy Rev.* **2015**, *43*, 843–862. [CrossRef]
170. de Alegría Mancisidor, I.M.; de Basurto Uraga, P.D.; de Alegría Mancisidor, I.M.; de Arbulo López, P.R. European Union's Renewable Energy Sources and Energy Efficiency Policy Review: The Spanish Perspective. *Renew. Sustain. Energy Rev.* **2009**, *13*, 100–114. [CrossRef]
171. Coenen, F.H.J.M.; Hoppe, T. Renewable Energy Communities as a New Actor in Home Energy Savings. *Urban Plan.* **2022**, *7*, 108–122. [CrossRef]
172. Chen, C.; Hu, Y.; Karuppiah, M.; Kumar, P.M. Artificial Intelligence on Economic Evaluation of Energy Efficiency and Renewable Energy Technologies. *Sustain. Energy Technol. Assess.* **2021**, *47*, 101358. [CrossRef]
173. Menniti, D.; Pinnarelli, A.; Sorrentino, N.; Vizza, P.; Barone, G.; Brusco, G.; Mendicino, S.; Mendicino, L.; Polizzi, G. Enabling Technologies for Energy Communities: Some Experimental Use Cases. *Energies* **2022**, *15*, 6374. [CrossRef]
174. Gagliardelli, L.; Zecchini, L.; Beneventano, D.; Simonini, G.; Bergamaschi, S.; Orsini, M.; Luca, M.; Emma, M.; Andrea, L.; Nicola, G. ECDP: A Big Data Platform for the Smart Monitoring of Local Energy Communities. In Proceedings of the Ceur Workshop Proceedings, Edinburgh, UK, 29 March–1 April 2022; Volume 3135.
175. Piselli, C.; Colladon, A.F.; Segneri, L.; Pisello, A.L. Evaluating and Improving Social Awareness of Energy Communities through Semantic Network Analysis of Online News. *Renew. Sustain. Energy Rev.* **2022**, *167*, 112792. [CrossRef]
176. Sănduleac, M.; Ciornei, I.; Toma, L.; Plămnescu, R.; Dumitrescu, A.-M.; Albu, M.M. High Reporting Rate Smart Metering Data for Enhanced Grid Monitoring and Services for Energy Communities. *IEEE Trans. Ind. Inform.* **2021**, *18*, 4039–4048. [CrossRef]
177. Patil, S.M.; Vijayalashmi, M.; Tapaskar, R. IoT Based Solar Energy Monitoring System. In Proceedings of the 2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS), Chennai, India, 1–2 August 2017; IEEE: New York, NY, USA, 2017; pp. 1574–1579.
178. Pesonen, K.; Korpijärvi, J.; Annala, S. Establishing a Decentralized Virtual Energy Community. In Proceedings of the 2023 19th International Conference on the European Energy Market (EEM), Lappeenranta, Finland, 6–8 June 2023; IEEE: New York, NY, USA, 2023; pp. 1–4.
179. Park, D.H.; Park, J.B.; Lee, K.Y.; Son, S.Y.; Roh, J.H. A Bidding-Based Peer-to-Peer Energy Transaction Model Considering the Green Energy Preference in Virtual Energy Community. *IEEE Access* **2021**, *9*, 87410–87419. [CrossRef]
180. USEF. *USEF—THE FRAMEWORK: A Solid Foundation for Smart Energy Futures*; USEF: Lexington, KY, USA, 2021.
181. Cutore, E.; Volpe, R.; Sgroi, R.; Fichera, A. Energy Management and Sustainability Assessment of Renewable Energy Communities: The Italian Context. *Energy Convers. Manag.* **2023**, *278*, 116713. [CrossRef]
182. Hussain, A.; Kim, H.-M. Enhancing Renewable Energy Use in Residential Communities: Analyzing Storage, Trading, and Combinations. *Sustainability* **2024**, *16*, 891. [CrossRef]
183. Rogers, J.C.; Simmons, E.A.; Convery, I.; Weatherall, A. Public Perceptions of Opportunities for Community-Based Renewable Energy Projects. *Energy Policy* **2008**, *36*, 4217–4226. [CrossRef]
184. Berry, D. Community Clean Energy Programs: Proficiencies and Practices. *Environ. Pract.* **2013**, *15*, 97–107. [CrossRef]
185. Europe and Energy Communities/Balkans/Areas/Homepage—Osservatorio Balcani e Caucaso Transeuropa. Available online: https://www.balcanicaucaso.org/eng/Areas/Balkans/Europe-and-energy-communities-223982 (accessed on 12 November 2023).

186. Caramizaru, A.; Uihlein, A. *Energy Communities: An Overview of Energy and Social Innovation*; Publications Office of the European Union: Luxembourg, 2020; Volume 30083.
187. Hanke, F.; Guyet, R. The Struggle of Energy Communities to Enhance Energy Justice: Insights from 113 German Cases. *Energy Sustain. Soc.* **2023**, *13*, 16. [CrossRef]
188. German Regulatory Framework—Energy Communities Hub. Available online: https://energycommunitieshub.com/country/germany/#_ftnref1 (accessed on 12 November 2023).
189. Legambiente. *Comunita-Rinnovabili-2021*; Legambiente: Rome, Italy, 2021.
190. Hinsch, A.; Rothballer, C.; Kittel, J. Renewable Energy Communities—Are We Nearly There? COME-RES. 2021, pp. 1–7. Available online: https://come-res.eu/fileadmin/user_upload/Materials/COME-RES-policy-brief-1.pdf (accessed on 10 October 2023).
191. Minuto, F.D.; Lanzini, A. Energy-Sharing Mechanisms for Energy Community Members under Different Asset Ownership Schemes and User Demand Profiles. *Renew. Sustain. Energy Rev.* **2022**, *168*, 112859. [CrossRef]
192. Zhang, C.; Wu, J.; Long, C.; Cheng, M. Review of Existing Peer-to-Peer Energy Trading Projects. *Energy Procedia* **2017**, *105*, 2563–2568. [CrossRef]
193. Moura, R.; Brito, M.C. Prosumer Aggregation Policies, Country Experience and Business Models. *Energy Policy* **2019**, *132*, 820–830. [CrossRef]
194. Feldman, D.; Brockway, A.M.; Ulrich, E.; Margolis, R. *Shared Solar. Current Landscape, Market Potential, and the Impact of Federal Securities Regulation*; National Renewable Energy Lab. (NREL): Golden, CO, USA, 2015.
195. BMWK—Gesetz Zur Änderung Des Erneuerbare-Energien-Gesetzes Und Weiterer Energierechtlicher Vorschriften. Available online: https://www.bmwk.de/Redaktion/DE/Artikel/Service/gesetz-zur-aenderung-des-eeg-und-weiterer-energierechtlicher-vorschriften.html (accessed on 17 November 2023).
196. Frieden, D.; Tuerk, A.; Neumann, C.; d'Herbemont, S.; Roberts, J. *Collective Self-Consumption and Energy Communities: Trends and Challenges in the Transposition of the EU Framework*; Compile: Graz, Austria, 2020.
197. ERSE—Autoconsumo. Available online: https://www.erse.pt/atividade/regulamentos-eletricidade/autoconsumo/ (accessed on 17 November 2023).
198. Gallego-Castillo, C.; Heleno, M.; Victoria, M. Self-Consumption for Energy Communities in Spain: A Regional Analysis under the New Legal Framework. *Energy Policy* **2021**, *150*, 112144. [CrossRef]
199. Hanke, F.; Lowitzsch, J. Empowering Vulnerable Consumers to Join Renewable Energy Communities—Towards an Inclusive Design of the Clean Energy Package. *Energies* **2020**, *13*, 1615. [CrossRef]
200. Tuerk, A.; Frieden, D.; Neumann, C.; Latanis, K.; Tsitsanis, A.; Kousouris, S.; Llorente, J.; Heimonen, I.; Reda, F.; Ala-Juusela, M. Integrating plus Energy Buildings and Districts with the EU Energy Community Framework: Regulatory Opportunities, Barriers and Technological Solutions. *Buildings* **2021**, *11*, 468. [CrossRef]
201. Pigliautile, I.; Breukers, S.; Boekelo, M.; Carnero, P.; Causone, F.; Arko, S.; Ferroni, S.; Pioppi, B.; Pisello, A.L.; Solar, A. Peer-to-Peer Energy Communities: Regulatory Barriers in the EU Context. *Open Res. Eur.* **2022**, *2*, 147. [CrossRef]
202. De Almeida, L.; Klausmann, N.; van Soest, H.; Cappelli, V. *Peer-to-Peer Trading and Energy Community in the Electricity Market-Analysing the Literature on Law and Regulation and Looking Ahead to Future Challenges*; Robert Schuman Centre for Advanced Studies (RSC), European University Institute: Fiesole, Italy, 2021; Volume 35.
203. Segreto, M.; Principe, L.; Desormeaux, A.; Torre, M.; Tomassetti, L.; Tratzi, P.; Paolini, V.; Petracchini, F. Trends in Social Acceptance of Renewable Energy across Europe—A Literature Review. *Int. J. Environ. Res. Public Health* **2020**, *17*, 9161. [CrossRef] [PubMed]
204. Dimovski, A.; Moncecchi, M.; Merlo, M. Impact of Energy Communities on the Distribution Network: An Italian Case Study. *Sustain. Energy Grids Netw.* **2023**, *35*, 101148. [CrossRef]
205. Tushar, W.; Yuen, C.; Saha, T.K.; Morstyn, T.; Chapman, A.C.; Alam, M.J.E.; Hanif, S.; Poor, H.V. Peer-to-Peer Energy Systems for Connected Communities: A Review of Recent Advances and Emerging Challenges. *Appl. Energy* **2021**, *282*, 116131. [CrossRef]
206. Oliveira, F.; Nogueira, P.; Casquiço, M. *Energy Agencies and Renewable Energy Communities: A New Path for Energy Decentralization*; European Energy Network: Strasbourg, France, 2022; Volume 57.
207. Sebi, C.; Vernay, A.-L. Community Renewable Energy in France: The State of Development and the Way Forward. *Energy Policy* **2020**, *147*, 111874. [CrossRef]
208. Moore, N.; Haines, V.; Lilley, D. Improving the Installation of Renewable Heating Technology in UK Social Housing Properties through User Centred Design. *Indoor Built Environ.* **2015**, *24*, 970–985. [CrossRef]
209. Pretlove, S.; Kade, S. Post Occupancy Evaluation of Social Housing Designed and Built to Code for Sustainable Homes Levels 3, 4 and 5. *Energy Build.* **2016**, *110*, 120–134. [CrossRef]
210. Botsaris, P.N.; Giourka, P.; Papatsounis, A.; Dimitriadou, P.; Goitia-Zabaleta, N.; Patsonakis, C. Developing a Business Case for a Renewable Energy Community in a Public Housing Settlement in Greece—The Case of a Student Housing and Its Challenges, Prospects and Barriers. *Sustainability* **2021**, *13*, 3792. [CrossRef]
211. Trevisan, R.; Ghiani, E.; Pilo, F. Renewable Energy Communities in Positive Energy Districts: A Governance and Realisation Framework in Compliance with the Italian Regulation. *Smart Cities* **2023**, *6*, 563–585. [CrossRef]
212. Bianchi, F.R.; Bosio, B.; Conte, F.; Massucco, S.; Mosaico, G.; Natrella, G.; Saviozzi, M. Modelling and Optimal Management of Renewable Energy Communities Using Reversible Solid Oxide Cells. *Appl. Energy* **2023**, *334*, 120657. [CrossRef]
213. Musolino, M.; Maggio, G.; D'Aleo, E.; Nicita, A. Three Case Studies to Explore Relevant Features of Emerging Renewable Energy Communities in Italy. *Renew. Energy* **2023**, *210*, 540–555. [CrossRef]

214. Lazzari, F.; Mor, G.; Cipriano, J.; Solsona, F.; Chemisana, D.; Guericke, D. Optimizing Planning and Operation of Renewable Energy Communities with Genetic Algorithms. *Appl. Energy* **2023**, *338*, 120906. [CrossRef]
215. Ahmadifar, A.; Ginocchi, M.; Golla, M.S.; Ponci, F.; Monti, A. Development of an Energy Management System for a Renewable Energy Community and Performance Analysis via Global Sensitivity Analysis. *IEEE Access* **2023**, *11*, 4131–4154. [CrossRef]
216. Gribiss, H.; Aghelinejad, M.M.; Yalaoui, F. Configuration Selection for Renewable Energy Community Using MCDM Methods. *Energies* **2023**, *16*, 2632. [CrossRef]
217. Spazzafumo, G.; Raimondi, G. Economic Assessment of Hydrogen Production in a Renewable Energy Community in Italy. *e-Prime-Advances Electr. Eng. Electron. Energy* **2023**, *4*, 100131. [CrossRef]
218. Aittahar, S.; de Villena, M.M.; Derval, G.; Castronovo, M.; Boukas, I.; Gemine, Q.; Ernst, D. Optimal Control of Renewable Energy Communities with Controllable Assets. *Front. Energy Res.* **2023**, *11*, 879041. [CrossRef]
219. Pasqui, M.; Felice, A.; Messagie, M.; Coosemans, T.; Bastianello, T.T.; Baldi, D.; Lubello, P.; Carcasci, C. A New Smart Batteries Management for Renewable Energy Communities. *Sustain. Energy Grids Netw.* **2023**, *34*, 101043. [CrossRef]
220. Faraji, J.; De Grève, Z.; Vallée, F. Hierarchical Energy Sharing Management for a Renewable Energy Community with Heterogeneous End-Users. In Proceedings of the 2023 IEEE Belgrade PowerTech, Belgrade, Serbia, 25–29 June 2023; IEEE: New York, NY, USA, 2023; pp. 1–8.
221. Ancona, M.A.; Baldi, F.; Branchini, L.; De Pascale, A.; Gianaroli, F.; Melino, F.; Ricci, M. Comparative Analysis of Renewable Energy Community Designs for District Heating Networks: Case Study of Corticella (Italy). *Energies* **2022**, *15*, 5248. [CrossRef]
222. Conte, F.; D'Antoni, F.; Natrella, G.; Merone, M. A New Hybrid AI Optimal Management Method for Renewable Energy Communities. *Energy AI* **2022**, *10*, 100197. [CrossRef]
223. Sudhoff, R.; Schreck, S.; Thiem, S.; Niessen, S. Operating Renewable Energy Communities to Reduce Power Peaks in the Distribution Grid: An Analysis on Grid-Friendliness, Different Shares of Participants, and Economic Benefits. *Energies* **2022**, *15*, 5468. [CrossRef]
224. Felice, A.; Rakocevic, L.; Peeters, L.; Messagie, M.; Coosemans, T.; Camargo, L.R. Renewable Energy Communities: Do They Have a Business Case in Flanders? *Appl. Energy* **2022**, *322*, 119419. [CrossRef]
225. Martens, K. Investigating Subnational Success Conditions to Foster Renewable Energy Community Co-Operatives. *Energy Policy* **2022**, *162*, 112796. [CrossRef]
226. Fina, B.; Monsberger, C.; Auer, H. Simulation or Estimation?—Two Approaches to Calculate Financial Benefits of Energy Communities. *J. Clean. Prod.* **2022**, *330*, 129733. [CrossRef]
227. Cosic, A.; Stadler, M.; Mansoor, M.; Zellinger, M. Mixed-Integer Linear Programming Based Optimization Strategies for Renewable Energy Communities. *Energy* **2021**, *237*, 121559. [CrossRef]
228. Conradie, P.D.; De Ruyck, O.; Saldien, J.; Ponnet, K. 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* **2021**, *151*, 112121. [CrossRef]