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Creation, growing and management of energy communities

Energy management framework for communities in the EU

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Executive summary

How can communities manage energy in the EU? Given diverse legislations of member states, evolving for convergence towards distributed renewable energy futures, a framework for management-related aspects of community-scale energy is timely and necessary. This report draws on an overview of related EU legislation, cutting-edge energy community (EC) research spanning 41 articles, and a focused review on the understudied aspect of intergenerational learning and ECs to fashion this approach. The framework includes attention to salient aspects in emergent thematic literature, highlighting issues of regulation and governance, and pinpointing gaps. The review constitutes the basis for a range of framework dimensions, which incorporate aspects of energy poverty, energy justice, economic benefits, participatory and trust-related concerns, political feasibility, and low-carbon technological options. This is synthesised into a framework and visualised to ease its uptake in practice. We moreover demonstrate operationalisation of the approach across four energy community cases of the RESCHOOL project, in Amsterdam, Athens, Girona, and Stockholm, to show how it is versatile and generative of insights across these diverse pilots and contexts. The framework is intended to guide rapid upscaling of energy flexibility solutions in these pilot cases, which will in turn serve as a means to validate and improve this version. The report aims to thus facilitate rapid yet thought-through diffusion of energy communities in the EU.

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1 Introduction

1.1 Regulatory evolution and the uptake of community energy in Europe

The value proposition that community energy offers to society and citizens is substantial, providing a wide range of economic, social, and environmental benefits. The benefits focus on actively involving citizens and businesses – so far mostly passive consumers of energy – in climate change mitigation, and empowering them to take ownership of the energy transition and their own decarbonisation process. Collectively producing and/or consuming green electricity (and additionally emergent renewable fuel solutions) is meant to reduce energy costs (e.g. in transport and heating), which in light of current energy price levels would alleviate risks of social unrest and poverty, and ease economic pressure on businesses and industry, particularly at local levels (Umar et al., 2022). Moreover, collective energy initiatives make local communities more resilient, through shorter supply and value chains, as well as improved labour markets and the advancement of skills that, in many EU regions, are urgently required for delivering on decarbonisation strategies, mainly through the deployment of renewable energy technologies and energy efficiency solutions. In parallel, active citizen participation strengthen democratic processes, social cohesion, and transparent governance models, which in combination with collective ownership and inclusive organisational and legal structures can create trust and foster acceptance of local renewable energy projects. The latter are often prevented or delayed by citizen groups who are concerned about environment, safety, or health, and by territorial incumbents. From a systems perspective, energy communities are key drivers for advancing decentralisation and digitalisation, which on the one hand improve autonomy and energy security, and on the other hand provide requisite flexibility for balancing local supply and demand. Smart energy management, in the form of storage, demand response, and other services provided to network operators, can reduce infrastructure costs, e.g., by avoiding investments in conventional grid extension.

Today, the large majority of Europe's citizen-led energy initiatives are cooperatives (Koltunov et al., 2023). These cooperatives can be understood as a type of social and economic enterprise that enables citizens to collectively own and manage renewable energy projects. According to the European network of citizens' energy cooperatives (REScoop.eu), there are about 3500 renewable energy cooperatives in Europe, mostly spread across the northwest of the continent and the Alpine region, often with a long-standing tradition, and built to foster rural electrification and local industries that typically emerged close to hydropower stations and Europe's earliest electricity networks. Through cooperatives, citizens (mostly but not necessarily) living in geographical proximity can invest in renewable generation by buying shares to finance a project and also consume the renewable energy that is being produced. The redistribution of profits is often limited, with surpluses being reinvested to support its members and/or the community, for instance through capped dividends or lower energy prices. Cooperatives operate on a voluntary basis through democratic governance to meet their members' needs, which can be economic, environmental, social, or cultural, with the aim of maximising local benefits rather than return on capital. Cooperatives are also the predominant form in most of the countries represented in the RESCHOOL project this report stems from, including Belgium, Germany, the Netherlands, Spain, Sweden, and Norway. Some of these cooperatives have developed into established energy market and system actors.

Building on this tradition and the many benefits cooperatives have been providing to Europeans for decades (in some cases for more than a century), and with strong support expressed by climate and energy stakeholders throughout an extensive consultation process, the legal reform adopted by EU decision-makers in 2018-2019, as part of the "Clean Energy Package" (CEP), established, for the first time in EU law, "renewable" as well as "citizen" energy communities as new actors in the energy sector. The CEP's recast Renewable Energy Directive (RED II) and the Internal Electricity Market Directive (IEMD) require Member States to introduce definitions and legislate on rights, duties, and potential market activities, establish enabling frameworks, and take energy communities into consideration when designing support schemes. The new provisions go beyond what many of Europe's traditional cooperatives offer today (e.g. with regard to energy sharing or effective control) and were designed to empower citizens and incentivise engagement as individual and collective self-consumers (or "prosumers"), by investing in joint renewable energy projects, with the intent to then consume, store or sell the energy produced, and thus benefit from functioning and organised energy markets.

Yet in practice, key to the effective growth of energy communities – in numbers and size – is the consequent transposition of EU provisions into national laws. This has been done to varying extents by EU Member States, both in terms of completeness and consistency. While some are making progress, such as Greece, Spain, and

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the Netherlands (Rescoop.eu, 2022), others (such as Sweden) lag behind, and have not introduced regulatory environments that can enable sustainable energy community project development.

Further regulatory evolution with significant potential to foster the uptake of energy communities could emanate from the recent European Commission reform proposal of the EU energy market design. Launching this reform follows on a series of emergency intervention measures, as the EU's policy response to Russia's invasion of Ukraine and its subsequent energy and cost-of-living crisis, delivered in the form of initiatives such as the 'REPowerEU'. This raises the EU's climate and energy ambition, including through higher 2030 targets for renewables (from previously 32% to 42.5% of renewable energy sources (RES) in the overall energy consumption), and energy efficiency (from previously 9% to 11.7% reduction of final energy consumption, compared to 2020 levels). The energy market design reform is expected to reach agreement among EU institutions by the end of 2023, with the main objectives being to accelerate the deployment of RES, phase out fossil fuels, and reduce price volatility for consumers. Although the European Commission does not propose any new specific regulation on energy communities, there are provisions that could benefit their development and sustainable growth – by allowing energy-sharing among households, public authorities, and small and medium enterprises (SMEs) (including between members of energy communities), enabling smaller actors to access renewable energy through power purchase agreements (PPAs), and increasing system flexibility through solutions that involve storage, demand response and aggregation.

1.2 The potential of energy communities in Europe's energy transition

In the transition to climate-neutral economies, there is no choice but to decarbonise the ways we produce and use energy. In the EU, the energy sector, including transport and heating, is responsible for close to 75% of the total greenhouse gas (GHG) emissions. This is why decision-makers have agreed, in particular under the European Green Deal, on ambitious EU climate and energy targets, which include reducing GHG emissions by 55% by 2030, and tripling the installed renewable capacity to reach the recently adopted 42.5% RES target. Reaching such levels by 2030, with just over six years remaining, requires profound transformations of energy markets and systems, and the exploitation of all available decarbonisation pathways – including the widely untapped potential of individual and collective self-consumption of renewable energy.

Studies have suggested in this context that individual households, energy communities, public entities, and small enterprises can make major contributions to the future decentralised energy system, estimating that by 2050, a total of 187 million, or 83% of all EU households, could be involved in renewable energy production, demand response, and/or energy storage. Changes in the population age distribution place stress on some of these links, affecting the economies of families, social groups, and energy systems. Besides millions of people driving electric vehicles and powering their smart homes with solar panels, batteries and heat pumps, this number could include 161 million who would be providing flexibility on the demand side. About half of all EU households, around 113 million, are expected to be producing renewable energy, with an estimated 64 million households doing so as members of energy communities. Already by 2030, energy communities could own as much as 17% of installed wind capacity and 21% of solar (Kampman et al., 2016).

This significant potential will only be exploited if the many persisting economic, regulatory, social and technical barriers are addressed and removed. In addition to policy and legal reform, capacity-building, and awareness-raising, this includes accessible funding and support schemes, which are made available in the form of regional, national and European support, such as the Recovery and Resilience Fund in response to COVID-19, as well as through the Just Transition Mechanism, the Cohesion Fund, and the European Structural and Investment Funds.

1.3 Research gap on energy community challenges and enablers from a governance perspective

The impact and feasibility of ECs depend on a range of aspects addressed in the social sciences and humanities (SSH), including distributional fairness, democracy, interpretations, organisation, and socio-technical factors. A number of reviews have recently been published on ECs as SSH perspectives. These reviews focus on an array of issues, and cover:

- ECs in general with regard to research approaches used (van der Schoor & Scholtens, 2019)
- Social sustainability with regard to
    - Citizen perspectives (Lazdins et al., 2021)
    - Energy justice (van Bommel & Höffken, 2021)

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    - General impacts (Gjorgievski et al., 2021)/
- Feasibility with regard to
    - Transition perspectives (Lode et al., 2022b)
    - Energy democracy and energy citizenship (Wahlund & Palm, 2022)
    - Social arrangements (Gjorgievski et al., 2021)
    - Business models (Iazzolino et al., 2022)
    - Government instruments (Leonhardt et al., 2022)

Considering the considerable interest in ECs in the EU, we identify that these reviews can be complemented by an up-to-date broad review of ECs, with a focus on just low-carbon energy transitions and feasibility, to provide comprehensive, practice-oriented guidance on EC governance.

1.4 Research gap on intergenerational learning

Boosting citizens' participation in energy communities remains challenging for municipalities due to the complex series of interactions this entails between individuals, groups, and the urgent need to decarbonise energy production and consumption and build systems that are powered and fuelled by RES. While intergenerational transfers are central to many important topics in economic demography, they are still understudied in the area or environment of energy communities in the EU. Since schools are a crucial part of this environment, to increase cooperation in initiatives within these energy communities, communication and participation tools between schools and energy communities must be explored. Schools, understood as strategic community spaces, can introduce these elements via intergenerational learning processes. Children can become knowledge-holders and leaders of intergenerational learning (IGL) processes, improving adult and community engagement. Although little research has been done to analyse IGL processes in energy communities, there is a large corpus of research tackling IGL in other areas. This scholarship supports the notion that intergenerational learning between related individuals is conducive to achieving new targets and inclusion for older people, as well as to fostering greater communication, understanding, and solidarity between generations. The aim of including a literature review with this focus is to learn and build on the previous knowledge from other areas to better design effective mechanisms of IGL in the energy communities' context.

1.5 Objectives and research questions

Objectives:

- To review and analyse state-of-the-art knowledge on the feasibility for different actors of energy communities in the EU.
- To focus on governance, regulatory, and sustainability related aspects of energy communities.
- To harness key governance insights pertaining to energy communities in RESCHOOL pilot contexts.

Research questions:

- How can energy communities in the EU become feasible and institutionalised?
- What main regulatory conditions govern the rollout of energy communities?
- What is the state-of-the-art on sustainability aspects of energy communities?
- What factors determine the feasibility of energy communities in the EU?

We are especially interested in addressing these questions in and across the four diverse pilot contexts in the RESCHOOL project. Hence, while regulatory treatment in this report relates to the EU, we extend a more detailed focus in relation to these case contexts to further develop through the RESCHOOL project.

1.6 Contribution of partners

Table 1 summarises the contributions by the project partners.

Table 1 Contribution of partners to the report

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Partner	Contribution
Centre for Research & Technology Hellas	Ioanna-Mirto Chatzigeorgiou contributed to setting the table of contents.
City of Amsterdam	Rutger Krabbendam contributed to data collection and analysis on the Dutch pilot.
Collective Energy	Alexandros Chronis and Nasos Vasilakis contributed to data collection and analysis on the Greek pilot.
Diputació de Girona	Anna Camp contributed to data collection and analysis on the Spanish pilot.
ElectriCITY	Annie Albåge, Josefin Danielsson, and Jörgen Lööf contributed to data collection and analysis on the Swedish pilot.
European Renewable Energies Federation	Johannes Vollmer contributed to setting the table of contents; wrote the first drafts of sections 1.1-1.2, 2.1, and 3.1; participated in the subsequent drafting process for the report; and approved the final report.
KMo	Santi Martínez, Xavi Massa, and Giulia Torri contributed to data collection and analysis on the Spanish pilot. Giulia Torri contributed to setting the table of contents.
OpenRemote	Pierre Kil contributed to data collection and analysis on the Dutch pilot.
Resourcefully Consulting	David Plomp contributed to data collection and analysis on the Dutch pilot. Hugo Niesing contributed to setting the table of contents.
University of Girona	Joaquim Meléndez i Frigola contributed to data collection and analysis on the Spanish pilot, and to setting the table of contents. Albert Sabater Coll and Anaïs Varo co-wrote the first drafts of sections 1.4, 2.3, and 3.3, participated in the subsequent drafting process for the report, and approved the final report.
University of Stavanger	Mathias Lindkvist coordinated the pilot data collection and analysis process; coordinated the report writing, wrote the first drafts of sections 1.3, 1.6, 2.2, 2.4-2.5, 3.4-3.6, and 4-5, led the first drafting of section 3.2, participated in the subsequent drafting process for the report, and approved the final report. Siddharth Sareen set up the pilot data collection and analysis processes, wrote the first drafts of the summary, and sections 1.4-1.5 and 1.7, co-wrote the first draft of section 3.2, participated in the subsequent drafting process for the report, and approved the final report.

1.7 Report structure

In the next section, we provide an overview of the methods and research techniques used for the reviews and overviews that address the research questions and are employed to develop a literature-based framework for management-related aspects of community-scale energy. Subsequently, the main results section is split into (a) a regulatory overview, (b) a review of EC scholarship, and (c) focused coverage of energy transition and sustainability related aspects, leading into (d) an energy community framework that is then (e) schematically applied to the four RESCHOOL pilot cases. The subsequent discussion section reflects upon the state-of-the-art and positions our contribution within evolving knowledge as well as in relation to the four RESCHOOL pilot cases. Finally, the conclusion offers remarks for future research and application of the framework.

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2 Methods

2.1 Regulatory overview

The methods used to develop the regulatory overview mainly consist of analysing consultant inputs and literature reviews of EU directives, as well as relevant studies and outcomes of related research projects, many of which are being conducted as part of the EU's Horizon 2020/Europe programme. In particular, the EU provisions on renewable and citizens energy communities have been analysed and assessed in detail, while the transposition into national laws is still ongoing, with monitoring by stakeholder groups (see REScoop.eu, 2023). In parallel, expertise and knowledge of the EU decision-making process that led to the adoption of the recast Renewable Energy Directive (Directive (EU) 2018/2001) and the Internal Electricity Market Directive (Directive (EU) 2019/944) as part of the Clean Energy Package in 2018-2019 is contributed by the authors[1] of **chapters 1.1, 1.2 and 3.1**, who have actively contributed throughout the entire policy-making process, including to the preparation, stakeholder consultations, and trialogue negotiations that were held on the EU rules on energy communities between 2014 and 2019, leading up to the CEP.

2.2 Systematic literature reviews

Two systematically designed literature reviews and a consideration of broad sustainability issues were used to map the state-of-the-art literature on ECs in an EU context. The first literature review focusses on ECs, while the second broadens the scope to energy transitions.

2.2.1 Review on energy communities

In order to provide as detailed explanatory EC guidance as possible, the scope of the EC-focussed review was set to social sciences and humanities (SSH) research, with a substantial part being qualitative approaches. The delimitation of the review was based on initial searches on or close to "energy communit*" and screenings of resulting entries.

The main search was performed in Scopus, after comparison to the search engines Web of Science and EBSCOhost. A keyword search based on the terms "energy community" and "community energy" with inclusion of documents from 2020 and onwards was used on 24 November 2022. Additional searches on inter alia "community", "innovation", "sustainable", and "development", and on "energy citizenship" were performed, which resulted in very similar results. The specific search used was on titles containing "energy communit*" or "community energy", filtered for subject areas "social sciences", "arts and humanities" or "multidisciplinary", after verifying that subject areas such as "business, management and accounting" did not result in substantially additional findings. The first search resulted in 139 documents. Based on their titles, 69 documents were selected for further study. After scanning the abstracts, 48 of the documents were selected for detailed study. Additional searches until 11 April 2023 and using the same approach, resulted in 55 documents. During the subsequent detailed document studies, additional documents were excluded due to lack of focus on qualitative SSH aspects on ECs in the EU, unavailability, or not being available in English. 41 documents remained for the main analysis in this EC-focussed review.

To provide a context-sensitive analysis and for efficiency reasons, a bottom-up approach inspired by the grounded theory (Glaser & Strauss, 1967) approach was used to analyse and categorise the 41 documents and subsequently to summarise the findings in a literature-based framework for management-related aspects of ECs.

2.2.2 Review on energy transitions

As a complement to the EC-focussed review, a review was carried out on energy transitions. A Scopus search was performed on 23 May 2023 on document titles including "energy transition*", from 2020 onwards, of review type, and in English. We further analysed the ten top cited resulting documents not already covered in the EC-focussed review, searching for potential additional findings to the findings from the EC-focussed review.

[1] The European Renewable Energies Federation (EREF)

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2.3 Review on intergenerational learning

The literature review on IGL consisted of a non-systematic review, prioritising empirical research papers and a few relevant review papers. The scope of the review includes both IGL experiences in energy communities as well as in similar areas, particularly sustainability-related topics. Besides this more general approach, two review subtopics have been included: educational intervention programs as well as research methods to evaluate IGL impacts. The initial corpus consisted of 50 papers, which were then screened down to 30 before a final selection of 23 articles. In this report, only the outputs for the most general approach are offered. A more comprehensive literature review will be presented in a future report within the RESCHOOL project.

2.4 Screening of broad sustainability aspects

Since ECs are being promoted largely for sustainability reasons, a broad reflection in relation to overarching sustainability issues is performed in relation to the reviews on ECs, energy transitions, and intergenerational learning. The topics covered in the reflection are the calls for considering all sustainability aspects as interlinked, as pointed out in the Agenda 2030 (UN, 2015), and the issue of other potential sub-optimisation at a global level, as highlighted through system dynamics studies (Herrington, 2021; Meadows et al., 1973).

2.5 Application of findings to case studies

In order to test the framework mainly derived from the EC-focussed review, this framework is applied to four pilots across the EU in the RESCHOOL project. The locations of the pilots are Amsterdam in the Netherlands, Athens in Greece, Girona in Spain, and Stockholm in Sweden. These pilots represent different types of ECs at distinct stages of development and in diverse contexts, and therefore illustrate the use of the framework in a versatile way. In the following, the basic logics of pilots are outlined, based on information as of February 2023.

Information on SSH related challenges and opportunities for the pilots was collected through interaction with the pilot partners in the projects, through a questionnaire with open-answer questions, bilateral online meetings, and a final joint online meeting.

2.5.1 Amsterdam, the Netherlands

The Amsterdam pilot focusses on EV chargers since they are flexible and consume large amounts of energy. Plans include integrating live meters for household in a scalable manner, a generic app which is applicable for household users, and a forecasting model for district energy consumption/production.

2.5.2 Athens, Greece

The Athens pilot focusses on development of PV projects for energy sharing, in other neighbouring regions via virtual net metering. The pilot considers energy vulnerability, since the municipality of Rafina-Pikermi will provide a list of vulnerable households that will benefit from the virtual net metering scheme. Introduction of demand-side management mechanisms through flexibility is planned.

2.5.3 Girona, Spain

The Girona EC pilot is a scheme that focusses on collective self-consumption in villages. The scheme has one basic pattern but is designed to be applicable to different types of villages, independent of village size, and with implementation by the villages. Capacity and services can be added without changing the basis. Four villages are involved, but 33 municipalities have already received grants to replicate the scheme.

The aims are to provide aggregators with flexibility services by aggregating distributed resources, and through the schemes, to impact the local grid in a manner that allows the distribution system operator (DSO) to decrease grid infrastructure investments by avoiding congestion.

2.5.4 Stockholm, Sweden

The energy community is planned to be established in a selected area in the neighbourhood Hammarby Sjöstad, since their transformer substations are likely to face a lack of capacity within a few years. The energy community is intended to provide services to the grid by balancing loads, using energy more smartly and effectively while also expanding local renewable energy production. Expected resources to be included are photovoltaics (PVs), batteries, load balancing, software to effectively manage distributed energy resources, and electric vehicles.

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3 Results

3.1 Regulatory aspects

Decision-makers have long emphasised that without putting consumers at the heart of Europe's energy transition, we would fall short of meeting our climate and energy goals, and not be able to effectively decarbonise over the next 2-3 decades. Consequently, the CEP, which was adopted in 2018-2019, introduced a strong set of measures meant to empower and protect consumers, namely through 1) better information and access to energy consumption data and costs, 2) a tighter safety net to address energy poverty and vulnerable consumers, 3) increased cost savings and energy-efficient behaviour through energy labels and eco-design measures, 4) more choice for consumers in their homes, and 5) facilitation of consumers' active role and engagement in individual and collective self-consumption – including through energy communities – and benefit from participating in functioning energy markets. This was the first time EU institutions introduced definitions and legal provisions on ECs, which was preceded by an extensive dialogue with the wider Brussels climate and energy stakeholder groups, held from 2014 onwards in the form of public consultations and expert workshops. These featured climate non-governmental organisations (NGOs) and renewable energy associations advocating for the establishment of clear and robust regulatory environments for community energy, whereas incumbent energy industries expressed concerns on related challenges, including consumer protection, security of supply, and the operation of electricity distribution networks. In consequence, the European Commission's initial CEP proposal, issued in late 2016, was welcomed by some stakeholders for its innovative and unprecedented design, while others criticised its wide scope and lack of precise requirements, which provides Member States with substantial flexibility in the legal interpretation and transposition.

The definitions and provisions on Renewable Energy Communities (Directive (EU) 2018/2001) (RECs) – called RED II – and Citizen Energy Communities (Directive (EU) 2019/944) (CECs) have been analysed and assessed in detail (COME RES, 2001). RED II defines RECs as legal entities which, in accordance with national law, are based on open and voluntary participation, effectively controlled by shareholders or members that are located in the proximity of the renewable energy projects owned and developed by that community. Shareholders or members can be natural persons, SMEs, or local authorities, with the primary purpose to provide environmental, economic or social community benefits for its members or the local areas where it operates, rather than financial profits. RED II further sets out to what RECs are meant to be entitled, i.e. the activities that can be carried out as well as the access to suitable energy markets. Member States are required to assess the potential of RECs as well as existing barriers. This assessment should precede the establishment of enabling frameworks for RECs that respect a number of minimum requirements, in terms of customer rights, administrative procedures, capacity-building and support schemes, and the cooperation with DSOs. While the IEMD definition and provisions for CECs (PROSEU, 2019) overlap with RED II regarding participation, control, purpose and its scope of activities, the main difference to RECs is that CECs are not geographically limited nor restricted to renewable sources, with the IEMD provisions referring to electricity only. In a nutshell, similarities and differences can be summarised as in Table 2.

Table 2 Summary of similarities and differences between renewable energy communities and citizen energy communities

	Renewable Energy Community (REC)	Citizen Energy Community (CEC)
Legal foundation	Renewable Energy Directive (Art. 2, Art. 22)	Internal Electricity Market Directive (Art. 2, Art. 16)
Sub-sector	Electricity, heating/cooling, transport	Electricity only
Technology	Only RES based technologies	Technology-open (fossil and RES based)
Legal form	Any	Any
Membership	Open, voluntary (→only natural persons, local authorities and SMEs whose participation does not constitute their primary economic activity. Participation accessible to all consumers including low-income and vulnerable households).	Open, voluntary (→any actor, if members/shareholders engaged in large scale commercial activity and for which the energy sector constitutes a primary area of economic activity do not exercise any decision-making power)

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Autonomy	RECs to remain autonomous from individual members and traditional market actors that participate in the community as members or shareholder	Autonomy is not required. Decision-making limited to those members or shareholders for which the energy sector does not constitute a primary area or economic activity.
Control and geographical limitation	Effective control by shareholders/members located in the proximity of the RE projects owned and developed by the legal entity; Member States may provide for RECs to be open to cross-border participation	Effective control by natural persons, local authorities or small enterprises; No geographic limitation, Member State can choose to allow cross-border Citizen Energy Communities
Primary purpose	Social, economic and environmental benefits for members/shareholders or the local area in which the entity operates	
Activities	Generation, distribution, consumption, storage, sale, aggregation, supply and sharing of renewable energy, energy-related services (commercial)	Generation, distribution, supply, consumption, aggregation, energy storage, energy efficiency services, charging services for EV, other energy-related services
Enabling framework, support schemes	Member State to provide enabling framework to promote and facilitate the development of RECs: • Remove unjustified regulatory/administrative barriers • Non-discriminatory treatment • Tools to facilitate access to finance and information • Regulatory and capacity-building support to public authorities in enabling and setting up RECs	Member State to provide an enabling regulatory framework for CECs: • Participation is open and voluntary • Members/shareholders entitled to leave • Members/shareholders do not lose their rights and obligations as household or active customers • DSOs cooperate with CECs to facilitate electricity transfers within the community • Transparent, non-discriminatory and cost-reflective network charges

In terms of regulatory treatment, the key difference between CECs and RECs lies in the nature of the Directives from which they emerge. The IEMD text formally recognises CECs as market actors and aims to create a level-playing field in the energy market, by defining CECs' entitlement and responsibilities among system and market actors along the energy value chain. The freedom for geographical extension also allows for virtual participation. RECs on the other hand emerge from the promotion of energy from renewable sources under RED II, putting greater emphasis on providing policy and regulatory support, such as for the design of schemes that allow RECs to compete for support on an equal footing with other market participants.

The transposition into national laws is challenged by a series of circumstances and regulatory features that go beyond establishing energy community frameworks: first, the very diverse reality and tradition of collective energy initiatives in Europe requires national lawmakers to not only take existing legal entities (such as cooperatives) and their rights and duties into account, but to also adapt energy market designs accordingly. Then, energy communities touch upon several areas of regulation, such as consumer protection and infrastructure rules, as well as supplier and network charging arrangements. Certain aspects, such as ownership of simple generation assets or the provision of direct services to the local community (such as advice on energy efficiency or initiatives to mitigate energy poverty) are, from a regulatory perspective, largely unproblematic. On the other hand, energy sharing within energy communities defies the classical supplier-customer relationship and requires defining clear frameworks. Although this was meant to be ensured through the REC

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provision in RED II, it has hardly been facilitated in practice by regulation anywhere in the EU – and is also for this reason being currently revised as part of the EU's energy market design reform.

Third, energy communities may, depending on which EU and national regulation applies, act as supplier or service provider (e.g., of aggregation and balancing services) or, if allowed, as network operator. These activities fall under the competence of electricity market regulation and go beyond energy community frameworks (for instance, RECs operating distribution networks would have to comply with all regulatory requirements that apply to DSOs). In consequence, national regulatory authorities pay particular attention when introducing new legal provisions that imply increasing complexity for the consumer. The same diligence applies when reforming market designs and optimise roles and responsibilities for all actors that are needed to deliver on Europe's climate ambition. This extends to market entrants such as aggregators and other energy service providers, revised tariff structures, and changing roles and obligations for transmission system operators (TSOs) and DSOs that are tasked to develop more flexible, smart and decarbonised infrastructures. It further encompasses rules related to data management and protection, and cyber-security, as well as a reinforced emissions trading scheme (with the recent agreement among EU institutions to include transport and buildings), accelerated and simplified permitting granting procedures for renewable energy projects, as well as the decarbonisation of gas markets and the uptake of green hydrogen. Each of such regulatory intervention is likely to also impact the development of enabling environments for energy communities.

In addition, national authorities face the question if and to what extent the many existing cooperatives can be treated as RECs or CECs from a regulatory perspective. While energy cooperatives comply to some extent with the provisions on autonomy, membership and most importantly, the primary purpose to provide social, economic and environmental benefits (rather than financial profits), there are important features and activities that RECs and CECs should be entitled to carry out but that many of today's cooperative models do not offer. For instance, this includes sharing renewable energy within an energy community, without brokerage of any third party, even when using the distribution network. Another crucial aspect of the REC's definition is geographical limitation: although the term "proximity" leaves room for legal interpretation, there are many energy cooperatives that are not being "effectively controlled by shareholders or members that are located in the proximity of the renewable energy projects". As such, the regulatory treatment of energy cooperatives can determine the ambition of Member States to establish enabling frameworks and amend existing provisions, allowing for existing initiatives to evolve and qualify as RECs or CECs – which in return might facilitate the further uptake of community energy. In any case, any preponderant regulatory compliance of cooperatives with the RED II and IEMD requirements should not be used by national authorities as a pretext to not improve relevant regulation and remove persisting barriers to further community energy development. Engaging with as many energy consumers as possible and establishing a substantially higher number of energy community initiatives, would complement the many well-functioning cooperatives that are operating across Europe – who can further develop their portfolio of activities and become economically more sustainable, and attractive to new members.

While the deadline for transposing RED II and IEMD into national law passed on 30 June 2021, most Member States have not sufficiently transposed the EU legislation on RECs and CECs into national laws. While there is progress made in three of the four countries that are home to RESCHOOL pilots (Spain, Greece, and the Netherlands), Sweden has not transposed any of the REC or CEC provisions into national law. In this context, it is important to note that regulatory progress does not exclusively depend on political preferences of decision-makers and vested interests of incumbent industries. Establishing new actors in markets and systems that were designed and have been operating to generate and transport energy largely made from nuclear and fossil fuels since more than 100 years ago presents a major challenge. Such profound transformation requires taking a holistic system approach for integrating emerging and existing layers of Europe's energy architecture – particularly in electricity, gas, heating and cooling, and transport.

3.2 Energy communities generally

3.2.1 Overview

An overview of the analysed 41 documents in the EC-focussed review is presented by source types in Table 3, document types in Table 4, publication years in Table 5, sources in Table 6, and countries and territories in Table 7. The documents are mainly journal articles of article type, with more publications from recent years and featuring multiple entries from the journals Energy Research & Social Science and Sustainability, and a research focus on the Netherlands, Germany, and a few other longer-standing EU Member States.

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Table 3 Source types

Source type	Number of documents
Journal	39
Conference proceeding	2

Table 4 Document types

Document type	Number of documents
Article	30
Review	5
Short survey	3
Conference paper	2
Note	1

Table 5 Years of publication

Year	Number of documents
2020	5
2021	13
2022	20
2023, until 11 April	3

Table 6 Sources

Source	Number of documents
Energy Research & Social Science	18
Sustainability	9
Heliyon	2 (each)
Isc2 2022 8th IEEE International Smart Cities Conference	
Energy Sustainability and Society	1 (each)
Environmental Innovation and Societal Transitions	
Environmental Policy and Governance	
Frontiers in Sustainable Cities	
International Journal of Sustainable Development and Planning	
Journal of Energy & Natural Resources Law	
Open Research Europe	
Science and Engineering Ethics	
Society & Natural Resources	
Urban Planning	

Table 7 Countries and territories

Country or territory, per corresponding authors or if no corresponding author per first author	Number of documents
Netherlands	9

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Germany	5
Spain	4
Belgium	3 (each)
Italy	
Portugal	
Austria	2 (each)
Canada	
Sweden	
Brazil	1 (each)
Ghana	
Ireland	
Japan	
Poland	
Slovenia	
Sweden	
Switzerland	
United Kingdom	

3.2.2 Just low-carbon transitions

3.2.2.1 Distributional aspects

3.2.2.1.1 Energy justice

The literature on energy justice features lack of inclusion in and beyond ECs, varied but limited attention to energy vulnerability, and gender imbalances. Laes and Bombaerts (2021) conceptually pinpoint opportunities for more research on local activities as negotiated rather than inherently inclusive. A review by van Bommel and Höffken (2021) finds ECs no guarantee for energy justice regarding the allocation of benefits across different societal groups, and critiques literature for its limited focus on trans-local effects, such as in relation to scarce materials in supply chains. Hanke et al. (2021) analyse 71 case studies regarding distributional, recognitional and procedural energy justice, to identify variations across ECs but commonly limited focus on energy vulnerability in approach and praxis. Bode's (2022) study on Germany find that for ECs to help alleviate energy poverty, well-established distributional injustices of schemes for benefit transfers and for housing need to be addressed. Lazoroska et al. (2021) use 11 solar energy community case studies in Sweden to unpack gender-related opportunities, and find few women included in the ECs despite participation being encouraged. Thus, an overall impression from scholars is that to deliver energy justice, ECs need explicit mechanisms towards this, but even with these in place, ECs may struggle to overcome complex context-specific political economy dynamics.

3.2.2.1.2 Economic benefit

Our review of publications on economic benefits highlights the monetary value of data and support for energy savings. Heuninckx et al.'s (2023) study of eight EU cases in Belgium, Denmark, Estonia, Italy, the Netherlands, and Spain, and one case in Colombia, identifies that requiring citizens to sign non-disclosure agreements in order to use their energy data in several cases led to some citizens becoming sceptical due to assuming that their data had a high monetary value. Coenen and Hoppe (2022) conclude, from seven case studies in Belgium, Denmark, France, Italy, Portugal, and Spain, that ECs can lead to lowering end-user energy bills through energy savings reached by, e.g., raising awareness.

3.2.2.1.3 Summary

The literature on distributional aspects mainly shows a range of challenges in safeguarding justice in and related to ECs. Topics covered by the publications are lack of inclusion in and beyond ECs, varied but limited focus on energy vulnerability, gender imbalances, uncertainties about distribution of economic benefits from data use, and ECs enabling energy cost savings.

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3.2.2.2 Influence

We identify findings on influence regarding the processes of initiating and scaling ECs and regarding challenges with opposing interests. Walker et al.'s (2022) review finds that ECs, to make sure that local interests are well addressed, ought to start with local interests and later in the process invite external actors to assist limited local availability of for example needed skills. The workshop summary by Loureiro et al. (2022) on four people-centric projects finds that energy democratisation can be achieved if all processes, including technology design, are participatory. Van Summeren et al.'s (2021) study of two cases in Flanders and the Netherlands, identifies that information and communication technologies (ICT) can be used in ways that over time lead to transformation where local control over electricity generation and supply is valued without meeting resistance from incumbent energy actors. Conceptually, Laes and Bombaerts (2021) identify opportunity for more research on how democratic influence can be ensured while leaving freedom for individual ECs. Wuebben et al.'s (2020) review on citizen science finds a need for research on how citizens can get more influence on energy production and consumption. Van Summeren et al. (2020), in a study on three community-based virtual power plants (cVPPs) in Belgium, Ireland and the Netherlands, find that cVPPs and other ECs will only contribute to a substantially more democratic energy system if EU Member States value the combination of aggregation and community. These publications on influence illustrate the usefulness of adapted processes for setting up ECs and show that currently conflicting interests may be overcome by nuancing institutional values and filling knowledge gaps.

3.2.2.3 Broad aspects

3.2.2.3.1 Aims of ECs

The literature on aims shows considerable variations across ECs, and also suggests that primarily environmental but also to a considerable degree economic and social aspects are the driving forces. Lode et al. (2022a) cover seven cases in Belgium, Greece, the Netherlands, and Spain regarding a range of EC stakeholders' objectives, and find great variation across the ECs, but note that the aspects considered most important are lowering emissions, community building, cost savings and increased stability of the grid. Soeiro and Ferreira Dias' (2020) survey, mainly on Portugal, Belgium and Spain, identifies environmental and climate concerns to be important reasons for setting up an EC, but notes that these motivations varied across ECs.

3.2.2.3.2 Social sustainability

In our analysis, scholarship on social sustainability highlights issues with lack of longitudinal assessments and the need for democratisation and decentralisation beyond an EC. A review by Bielig et al. (2022) concludes that quantitative and longitudinal evaluations of the social impact of ECs were missing, and that assessment of social impacts should be included in research and funding of ECs. Otamendi-Irizar et al.'s (2022) study of 11 cases in Belgium, Denmark, Germany, Italy, the Netherlands, and Spain finds that increased democratisation and decentralisation is important to achieve beyond ECs for them to substantially contribute to local social sustainability, requiring autonomous community management and political support of a considerable transition.

3.2.2.3.3 Environmental sustainability

The studied literature on environmental sustainability reveals both environmental challenges and opportunities for ECs. Dall-Orsoletta et al.'s (2022) review, on social innovation and community energy transitions, find that community-based initiatives have limited opportunity to be key components of sustainability transitions, because of the power held by incumbent energy actors when decisions are made. The Coenen and Hoppe (2022) study of seven cases in Belgium, Denmark, France, Italy, Portugal and Spain, identifies ECs as potentially useful for supporting awareness-raising on energy aspects such as climate change, e.g., by training.

3.2.2.3.4 Summary

In summary, our review on broader aspects highlights both challenges and opportunities regarding environmental and social sustainability. The challenges concern lack of longitudinal social assessments, need for democratisation and decentralisation beyond ECs, and environmental challenges due to incumbent energy actors. Opportunities are found in environmental sustainability motivations that drive the setting up of ECs, and in ECs themselves contributing to environmental awareness-raising.

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3.2.3 Feasibility

3.2.3.1 Governance

3.2.3.1.1 Governance in or close to ECs

Our analysis of literature on the organisation of ECs reveals a range of challenges, drivers, and mechanisms to enable these drivers, as reported sequentially below.

Scholarship on challenges identifies knowledge gaps. Blasch et al. (2021) conceptually argue for more EC research on the viability of emerging business models, on potential value of ECs, and on their impact assessment. Frieden et al. (2021) find a lack of knowledge on broader energy system integration in cases spanning Austria, Croatia, Greece, Portugal, Slovenia, and Spain, indicating a lack of holistic planning on ECs. Barroco Fontes Cunha et al.'s (2021) case study in Italy underscores a need to combine learning and doing, to match visions with quantitative impact planning across spatial scales. Taylor et al. (2021) develop educational material to help researchers safeguard against over-studying specific, limited types of typically rural energy communities. The challenges presented by these publications are natural at an emergent stage, but given the ambition of rapid action, the challenges need to be addressed systematically.

Drivers of ECs focus on establishing and running them. De Vidovich et al.'s (2023) three case studies across Italy conclude by calling for stronger planning competencies in public administration to enable context-sensitive approaches. Case study analysis in Italy and the Netherlands helps Tarpani et al. (2022) argue that pioneer countries should consider featuring more heterogeneity within ECs. Van Summeren et al.'s (2022) study of Dutch and Flemish cases of virtual power plants shows the viability of collaborating with similar initiatives to handle institutional uncertainty and ambiguity. Frieden et al.'s (2021) study of Austria, Croatia, Greece, Portugal, Slovenia, and Spain identifies a need to address how to overcome practical challenges to ECs present in complex procedures for licencing, registration and accessing data. The enablers found in these scholarships speak back to the need to simplify and streamline regulations and technocratic mechanisms to enable ECs.

Some studies take a longer and broader view of nuanced drivers. Barroco Fontes Cunha et al. (2021) find that public administration had an important role in sustaining an Italian EC. Lode et al. (2021) test a participatory tool in a Dutch case study and find it useful to help integrating different stakeholder criteria early in the process of the EC. In a comparison of four cases in Germany and the Netherlands, Dóci (2021) find a lack of structure in the organisation of an EC to lead to conflicts and recommend a continuous high level of involvement and information flow. Such requirements can in turn place demands on participants. Petrovics et al.'s (2022b) review identifies simplicity, being organised, interaction, support, and conducting innovation in predictable surroundings as key enablers. In another review-based study, Petrovics et al. (2022a) highlight sharing and synthesis of visions across ECs as key for larger systems change. Boyle et al. (2021) draw on nine case studies in Ireland to underscore the role of locally established organisations in scaling through networking and trust. Finally, Ehrtmann et al. (2021) analyse eight ECs and six intermediaries in Germany to argue that regional business collaborations on electricity through hybrid actor networks can contribute to sustainable system transformation.

Literature on mechanisms to enable drivers covers differentiation across countries, and EC sizes and types. Tarpani et al.'s (2022) study of Italian and Dutch cases find that ECs in laggard countries should prioritise community participation. Dóci (2021) compares four cases in Germany and the Netherlands to highlight the need for an externally hired manager to organise larger ECs, as an EC with over around 1,000 members otherwise struggle with trust. Van Summeren et al. (2020), in a study on three community-based virtual power plants (cVPPs) in Belgium, Ireland and the Netherlands, find that these can be useful to overcome institutional obstacles for selling electricity. To summarise the scholarships on mechanisms, ECs do have a range of options for success to consider at their disposal, anchored in diverse EU contexts.

3.2.3.1.2 Governance further away from ECs

The studied literature on governance further away from ECs provides overviews and insights on system integration and knowledge gaps.

The overviews focus on laggards and pioneers, energy transitions, and renewable citizen ECs (RCECs). Based on two case studies in Italy and the Netherlands, Tarpani et al. (2022) find improved economic EC prospects useful; opportunities for laggard countries to focus on clearer law-making and on highlighting ECs as alternatives to grid limits and their sustainability gain; and that pioneer countries could shift the focus towards flexibility. In a

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conceptual study on the desired German energy transition, Broska et al. (2022) identify that ECs will only be part of such a transition if regulation is improved and related administration is removed, and if further economic support is given to socioeconomically weak groups. Sokołowski (2020) conceptually finds it useful to establish an RCEC framework that combines the REC and CEC frameworks. The overviews thus show a range of challenges and opportunities.

Regarding system integration, the articles analysed address vertical integration and complex ECs. Krug et al. (2022) study the cases of Germany and Italy and identify a need for furthering the process of coordinating between national and regional governments. Leonhardt et al.'s (2022) review concludes that locally developed policies to promote CE in many cases have contradicted national policy. In their study on cases of integrated local ECs, which include a complex set-up of energy production, storage, and use, in Italy, Portugal and Poland, Morch et al. (2022) find challenges regarding ownership of energy storage facilities and lack of coordination across energy regulation on heat, hydrogen and electricity, and their respective networks.

The articles on knowledge gaps cover governance evaluations, policy continuously adapting to technology, contextualisation, and cVPPs. Krug et al.'s (2022) study on the cases of Germany and Italy find a need for more research on the effectiveness of EC governance options. A review by Leonhardt et al. (2022) identifies the need for further research to help policies keep up to date with technology development and help policies be more economically feasible in the long-term by addressing root issues. Blasch et al. (2021) conceptually find the need for more research that compares different institutional contexts to provide case-relevant policy-making guidance. Van Summeren et al.'s (2020) study on three cVPPs in Belgium, Ireland, and the Netherlands, identify the need for more research on the roles of cVPPs in the energy system and on institutional obstacles in relation to cVPPs. To summarise the publications on knowledge gaps, they identify gaps on governance, economic feasibility, technology, and context.

3.2.3.1.3 Summary

The EC publications on governance cover a range of aspects. The literature on governance in and close to ECs highlights challenges regarding long-term planning, energy systems, business values, values and research fatigue; enablers being strong support from public administration, interaction, local embeddedness, heterogeneity inside ECs, innovation, simplicity, structured organisation and predictable surroundings; and findings on how to enable drivers regarding prioritising community participation, professional management for larger ECs, and VPPs to facilitate selling electricity. Regarding governance further away from EC, findings highlight potential economical EC disadvantages; the need for clearer law-making and clarification of benefits regarding grid limits and sustainability; usefulness of creating RCEC policy; the removal of regulatory barriers and support to socioeconomically weak groups to enable transition; need for policy integration; challenges regarding ownership of energy storage; and the need for research on governance evaluations, continuous policy adaptations to technology, contextualisation, and cVPPs.

3.2.3.2 Participation

3.2.3.2.1 Citizens

Our analysed literature on citizens focuses on participation as bottleneck, living labs, communitarian versus market aspects, and citizen science. Broska et al. (2022) test a model with a focus on Germany with case study data, and find that current trends in their studied context in development of economic and regulatory framework conditions, such as continued limited support for socioeconomically weak groups, are unlikely to lead to enough citizen participation from different socioeconomic groups for ECs to play an important energy transition role. Sidqi et al.'s (2022) conceptual study on methods for empowering citizens in ECs identifies that living labs allow for co-production of knowledge for innovation and active participation. Laes and Bombaerts (2021) conceptually call for more research on how prominent communitarian aspects are in ECs and on how well communitarianism works in a market economy. Wuebben et al.'s (2020) review on citizen science finds relevance in disseminating benefits of ECs through different methods such as surveys and storytelling, identifies a need for research on actual use of data gathering through e.g. smart meters, and argues that citizen science-informed intermediaries can help disseminate knowledge on ECs. The publications on citizens thus provide insights on challenges in and beyond ECs and success factors regarding certain aspects.

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3.2.3.2.2 Learning

The reviewed publications on learning consider informality, accessibility, personal relevance, and need for research on how intra- and inter-learning in ECs take place. Medved et al.'s (2023) study of cases in Germany, Italy, the Netherlands, Slovenia, and Sweden concludes that most of the learning occurred in informal settings, and that accessibility and personal relevance were important for effective learning. Blasch et al. (2021) conceptually identify a need for research on how ECs learn from one another, and on how to support learning.

3.2.3.2.3 Social relationships

The studied literature on relationships cover the importance of social relations and trust. Savelli and Morstyn's (2021) perspective article identifies that a means towards effective ECs could be to base them on social relationships but that more research is needed, e.g. on their contextualisation. Soeiro and Ferreira Dias (2020) use a survey study mainly on Portugal, Belgium, and Spain, to find that trust is an important condition for starting an EC, but that these conditions vary across ECs. The two publications show the importance of context for addressing social relationships.

3.2.3.2.4 Summary

The publications on participation highlight a range of challenges and opportunities. Findings cover participation as a bottleneck, effectiveness of living labs, communitarian versus market aspects, and the utility of citizen science; learning regarding the usefulness of informality, accessibility, personal relevance, and knowledge gaps on intra- and inter-learning in ECs; and the importance of social relationships, and of trust, especially in early phases.

3.2.3.3 Other aspects

The reviewed literature on roles of other aspects covers technology regarding challenges with automation, with guiding citizens, and with complexities, and opportunities of decreased pressure on the electricity grid, and presence of ECs across the EU. Abu-Kankam and Camarinha-Matos' (2022) review covering 32 case studies of emerging ECs finds a need for automated decision-making, but notes that very few of the cases considered such integrative technology. Minuto et al.'s (2022) study of 30 software tools concludes that none of these tools can guide self-organised citizens through all the phases of setting up an EC. In a study on cases of integrated local ECs, which include a complex set-up of energy production, storage, and use, in Italy, Portugal and Poland, Morch et al. (2022) identify challenges regarding varying readiness level, low flexibility, and space requirements. Using two case studies in Italy and the Netherlands, Tarpani et al. (2022) conclude that pioneer countries could gain less pressure on the electricity grid from community-based smart grids. Finally, Capellán-Pérez et al.'s (2020) overview finds limited but potentially rapidly emerging presence of ECs in post-socialist EU countries. This lack of presence across countries limits the possibility to draw conclusions for all EU countries based on existing literature.

3.3 Intergenerational learning from an energy community perspective

While the main focus of attention in shaping the success of energy communities has been placed at the individual and organisational level, there is a growing realisation that it is crucial to embrace the potential of social contagion effects between generations due to their differential energy usage. And we know that the current structures of energy consumption in many countries are unsustainable in the face of population ageing. Within this context, pedagogical approaches that consider that older adults are more energy-intensive than younger adults and less likely to adopt energy efficient practices, or engage in the use and/or production of renewable energies, have been put forward to address information imbalances and behavioural change. Thus unsurprisingly, intergenerational learning processes have gained significant attention in the literature (Martins et al., 2019; Stephan, 2021). These processes involve the transfer of knowledge and practices between different generations within families and communities. Schmidt-Hertha (2014) proposed three core principles of intergenerational learning in the family, including learning about one's own and other generations, reciprocal exchanges, and shared commitments. Stephan (2021) added a fourth principle, emphasising the importance of relationship-building to establish deeper connections between family members.

Environmental education plays a relevant role in building science capital, which encompasses science-related resources accumulated throughout a person's life (DeWitt et al., 2016, cited by Gilleran et al., 2021). In the specific field of energy, to improve energy behaviour it is not enough with technical knowledge of how the energy system works, but a broader understanding of science capital related to energy is needed, which should include knowledge, but also practices and day-to-day engagement. Understanding energy demand within the

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energy sector requires considering it because of social practices, as emphasised by Shove and Walker (2014). Isabelle (2011) specifically highlights intergenerational differences and how different generations influence each other in energy behaviour from a practice-theory approach.

The earliest studies on intergenerational learning about environmental topics date back to the beginning of the 1990s (Duvall & Zint, 2017). Sutherland and Ham (1992) conducted one of the foundational investigations in this field, in which they analysed child-to-parent transfers through an environmental education program in two elementary schools in Costa Rica. Uzzell (1994) explored the potential of child-to-parent transmission and the role of children as catalysts for environmental action, going beyond the previous knowledge-focused studies.

In this same direction, intergenerational learning was initially recognised for its potential to transfer knowledge, but it soon became evident that it could also drive environmental behaviour change and community engagement (Uzzell, 1994). Therefore, intergenerational and intercommunity learning can empower children to become educators and inspire community environmental action (Vaughan et al., 2003). While intergenerational learning often takes place informally, school activities can enhance its potential (Istead & Shapiro, 2014). For this reason, schools or other formal or semi-formal educational contexts become crucial to implementing and developing these types of programs.

Whereas most previous studies have focused on intergenerational transfers and learning from children to parents, a few investigations have expanded the scope to include other community members such as elders, grandparents, relatives, neighbours, and community members (D'Abundo et al., 2011). This broader perspective recognises the potential for intergenerational learning beyond immediate family relationships, and to promote community-level transformations (Vaughan et al., 2003).

The body of research on intergenerational learning processes related to environmental issues is extensive and employs diverse research methods, including quantitative studies (e.g. Vaughan et al., 2003; D'Abundo et al., 2011; Boudet et al., 2016; Gill & Lang, 2018; Lawson et al., 2019, Mikami et al., 2022; Wang et al., 2022), qualitative studies (Williams et al., 2017; Chineka & Yasukawa, 2020; Istead & Shapiro, 2014) and mixed-methods approaches (Gilleran Stephens et al., 2021; Deng et al., 2022). From our literature review analysis, although the majority of research has focused on quantitative methods, the results are richer when obtained from mixed methods approaches examining intergenerational effects from different perspectives and with enough diverse data to triangulate results.

3.4 Energy transitions and general sustainability

The reviewed energy transition literature further emphasises some challenges that the EC-focussed review highlighted. Deeper concern is voiced for incumbents continuing to defend vested interests and benefit from clean energy transition (Carley & Konisky, 2020), and for gender and social equity not being achieved by energy transitions alone, but rather requiring more structural socio-cultural and socio-economic change (Johnson et al., 2020). Scholarship also identifies limitations posed by culture on end-users regarding the use of new technology and adoption of new habits (Sovacool & Griffiths, 2020).

The general sustainability issues of joint action across all sustainability issues and risks of global sub-optimisation are not directly covered by the EC-focussed or the energy transition-focused review. These general aspects are in themselves challenging to research, yet are nonetheless valuable to consider in any given case.

3.5 An energy management framework

Table 8 provides a literature-based framework for management-related aspects of ECs in the EU, by synthesising the findings from the regulatory overview, the EC review, and the review on IGL. The framework provides a list of aspects for ECs to consider.

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Table 8 A literature-based framework for management-related aspects of energy communities (ECs) in the EU

Theme	Sub-theme	Details, if applicable
Regulation	Enshrined into law at EU level since 2018-2019 on renewable energy communities and citizen energy communities, transposed to different degrees into Member States regulations	
	Potential energy market design challenges for e.g. ECs sharing energy since this conflicts with established actor relationships	
(Potential) challenges for supporting sustainability transitions	Inclusion, democratisation, and decentralisation lacking in and beyond ECs, such as in supply chains	
	Socioeconomically weak groups lacking support	
	Conflicting interests, including regarding democracy in relation to EC freedom	
	Regulatory obstacles	
(Potential) other challenges for ECs	Knowledge gaps	Impact Benefits Longitudinal impact assessments Business models Data use Technology systems Energy system integration Community-based virtual power plants Learning Combined learning and doing Learning across ECs How to support learning Lack of software supporting self-organised ECs Other Communitarianism's role Social relationships Governance effectiveness Institutional contextualisation Technology knowledge not up to date in policy
	Distributional fairness	Aims variation across ECs Energy vulnerability Gender imbalance Too homogeneous
	Conditions	Economic Economic EC conditions being weak Benefits distribution uncertain Ownership of energy storage facilities

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		Technical Technology readiness level variation Technology flexibility low Technology facilities space lacking Lack of automatising Research fatigue Regulation Lack of public administration planning Complex licencing, registration, and data access Unclear law-making
(Potential) opportunities that support sustainability transitions	Regional business collaboration	
(Potential) other opportunities for effective ECs	Gains	Environmental awareness raising Cost savings on energy Electricity sales enabling through virtual power plants Electricity grid pressure lowering
	Collaboration enablers	Generally Trust Interaction Community participation Social relationships Stakeholder criteria integration Living lab for innovation and participation Support for collaboration Institutional challenges handled by ECs collaborating Locally established organisations Predictable surroundings Policy integration in EU, vertically, and across sectors
	Learning enablers	Informal settings Accessibility of information Personal relevance Disseminate benefits insights with different methods Disseminate by citizen science-informed intermediary Intergenerational learning can benefit from formality
	Other enablers	Process Start from the local Hire a manager for an EC above 1000 members Approach Structure ECs well Simplicity Innovation

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		Shift towards flexibility

3.6 Schematic application across RESCHOOL pilot cases

The literature-based framework for management-related aspects of ECs is schematically applied across four RESCHOOL pilot cases. The purpose is to indicate how it can serve as a useful tool for comparative application. Table 9 shows aspects the four RESCHOOL pilots have considered in the framework. We did not identify the framework to lack any of central aspects of the four pilots. It can also be noted that the framework covers a considerably broader range of aspects than our study of the four pilots, and this illustrates the relevance of considering the whole framework instead of a limited selection of cases, and indicates that the four pilots may thus find further input on how they could be organised.

Table 9 Aspects the four RESCHOOL pilots have considered in the literature-based framework for management-related aspects of energy communities. ES = Spain, GR = Greece, NL = Netherlands, and SE = Sweden.

Theme	Sub-theme	Details, if applicable
Regulation	Potential energy market design challenges for e.g. ECs sharing energy since this conflicts with established actor relationships (GR, SE)	
(Potential) other challenges for ECs	Knowledge gaps	Impact Business models (SE)
	Distributional fairness	Energy vulnerability (ES, NL, SE) Too homogeneous (GR, NL, SE)
	Conditions	Economic Economic EC conditions being weak (SE) Regulation Unclear law-making (GR)
(Potential) other opportunities for effective ECs	Gains	Cost savings on energy (GR, SE) Electricity grid pressure lowering (ES, NL, SE)
	Collaboration enablers	Generally Trust (ES, SE) Interaction (ES, SE) Community participation (ES) Social relationships (ES, SE) Support for collaboration Institutional challenges handled by ECs collaborating (GR) Locally established organisations (ES, SE)
	Learning enablers	Informal settings (SE)
	Other enablers	Process Start from the local (ES, GR, SE) Approach Simplicity (ES) Innovation (ES, GR, NL, SE) Shift towards flexibility (ES, GR, NL, SE)

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4 Discussion

The developed literature-based framework for management-related aspects of ECs provides a list of a range of aspects that can be relevant for an EC in the EU or a comparable context. This list is the result of an overview of EU regulation on ECs, a state-of-the-art EC review with a bottom-up perspective, and a review on IGL. The resulting framework can therefore complement the generally more theoretically driven reviews and frameworks on ECs, on, e.g., research approaches used (van der Schoor & Scholtens, 2019), transition perspectives (Lode et al., 2022b), and energy democracy and energy citizenship (Wahlund & Palm, 2022).

The list of potentially relevant aspects in the framework is a starting point but does provide limited contextualisation. Contextualisation is typically not part of the conclusions that the framework is based on, and this lack is expected given the complexity of energy transitions and the novelty of ECs in their current form. Nevertheless, the context ought to be considered when applying the framework, bearing in mind that aspects not covered in the framework may be central for a given EC.

5 Conclusion

A framework for management-related aspects of community-scale energy is timely and necessary. This report draws on an overview of related EU legislation, cutting-edge energy community research spanning 41 articles, and a review on intergenerational learning and ECs to fashion this framework. The framework includes attention to salient aspects in emergent thematic literature, highlighting issues of regulation and governance, and pinpointing gaps. The review constitutes the basis for a range of framework dimensions, which incorporate aspects of energy poverty, energy justice, economic benefits, participatory and trust-related concerns, political feasibility, and low-carbon technological options. This is synthesised into a framework and visualised to ease its uptake in practice. We demonstrate operationalisation of the framework across four energy community cases of the RESCHOOL project, in Amsterdam, Athens, Girona, and Stockholm, and this application shows the feasibility and versatility of the framework by covering aspects central to the pilots and many additional ones.

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Annex: Glossary

CEC: Citizen energy community

CEP: Clean Energy Package

cVPP: Community-based virtual power plant

DSO: Distribution system operator

EC: Energy community

ES: Spain

EU: European Union

EV: Electric vehicle

GHG: Greenhouse gas

GR: Greece

ICT: Information and communication technology

IEMD: Internal Electricity Market Directive

IGL: Intergenerational learning

NGO: Non-governmental organisation

NL: Netherlands

PPA: Power purchasing agreement

PV: Photovoltaic

RCEC: Renewable citizen energy community

REC: Renewable energy community

RED II: CEP's recast Renewale Energy Directive

RES: Renewable eneregy sources

SE: Sweden

SME: Small and medium enterprise

SSH: Social sciences and humanities

TSO: Transmission system operator

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