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Review

Terminologies and concepts of energy cooperations in Europe: A systematic review of characteristics, potentials, and challenges

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ABSTRACT

The development of energy communities and the promotion of decarbonisation of settlements through the implementation of renewable and local energy production sources has been emphasised in recent years by European agreements and agendas such as the European Green Deal, the Clean Energy for All Europeans Package, or the REPowerEU Plan. While these directives focus on Renewable Energy Communities and Citizen Energy Communities, the range of terms used in the field is much wider. For this reason, an in-depth analysis of academic literature on European energy cooperation initiatives was carried out for a five-year period between 2018 and 2023. This comprehensive literature review allowed to identify the types of cooperative energy initiatives that are being promoted in Europe to support the climate neutrality targets. The paper presents a systematic overview of the different terms used to describe energy cooperation initiatives, their organisational forms, the main actors involved, and their roles and levels of participation, the main purposes and motivations, social cohesion factors, financing systems and economic models, as well as challenges and benefits encountered. The findings allow to identify challenges and innovations that can more successfully promote the different forms of energy cooperations and thus support the decarbonisation of cities and communities by decentralising energy, using local and more sustainable resources, transgressing the current social, legal and market regulations, and involving different local actors, especially citizens, in the process.

1. Introduction

Although the energy transition has an important technological dimension, it also requires a broader societal change [1]. Today's energy schemes are facing essential changes driven by, among others, climate issues, digitalisation growth, and increasing demand for a more engaged and active participation of citizens [2]. In this regard, as Savelli and Morstyn [3] indicate, social interactions have the potential to enhance the involvement of actors to act cooperatively towards shared objectives. Citizen-led energy cooperation initiatives have a long history across Europe but have recently gained significant momentum following their recognition in EU energy policy frameworks. This recognition is highlighted by European agreements and agendas such as the 2019 European Green Deal [4] and the Clean Energy for All Europeans Package [5], which includes eight new laws to shape the transition to a cleaner, more sustainable energy system. Among these laws are the Energy Efficiency Directive (EU/2023/1791) and the Energy Performance of Buildings Directive (EU/2024/1275), as well as the Renewable Energy Sources Directive II (REDII) (EU/2018/2001) [6], which defines collective and individual self-consumption, outlines the development of Renewable Energy Communities (RECs), removes regulatory barriers, and ensures transparent procedures. Additionally, it includes the Regulation on the Governance of the Energy Union (EU/2018/1999), and the Electricity Market Directive (EU/2019/944), also known as the Fourth Electricity Directive (FED) [7], which focuses on electricity market rules and consumer protection and introduces the concept of Citizen Energy Communities (CECs) [8]. The FED requires member states to adjust their regulatory frameworks to cover grid operator contracts, appropriate grid charges, and ensure non-discrimination of customers connected to the distribution system. These laws, followed by the 2022 REPowerEU Plan [9,10] to address energy challenges and reduce fossil fuel dependency, mandate that at least 42.5 % of energy consumption must come from renewable sources by 2030, with an ambition to reach 45 %. The directives also require

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member states to establish a legal framework for both Renewable Energy Communities (RECs) and Citizen Energy Communities (CECs). In consequence, many countries have started to transpose EU legislation into their national laws. In Spain, for example, RECs and Energy Communities (ECs) as well as energy Self-Consumption (SC) are legally regulated, but the concept of CECs is not yet included in its legal system [11]. Germany, which is considered one of the pioneering countries towards a low-carbon energy system, has developed a strong legal support system for the implementation of Energy Communities and, in addition, has introduced the concept of "Citizens Energy Companies" to foster the diversity of actors involved in the energy transition [12]. Similar efforts exist in many other countries such as, for example, in Greece, whose Law 4513/2018 represents an innovative and comprehensive institutional intervention strengthening the social economy in the energy sector [12]. In general, it is noted that in countries with a long-standing tradition of cooperative movements, citizens are typically better-versed in the legal structures and related benefits [13]. In contrast, countries less familiar with the cooperative model may face more significant challenges [14].

The high dynamics in the field of decentralised cooperative energy initiatives over the past years has spurred innovative development projects to support the energy transition across Europe and is also reflected in the large number of academic publications on this topic that have appeared in recent years [10]. Scholars have built a solid research base on energy cooperations by examining this phenomenon through social arrangements and innovation across the EU [15–17], providing comprehensive inventory studies [18,19], analysing statistical evidence [20], and reviewing technical designs as well as environmental and socioeconomic impacts [21,22]. As part of this development, a wide variety of terms has emerged to describe cooperative initiatives in the energy sector [6,7,9,23], going far beyond the two definitions published by the European Commission – Citizen Energy Communities (CECs) and Renewable Energy Communities (RECs) [6,7]. These various terms are based on different characteristics such as participants, purposes, legal forms, governance systems, or main activities and range from "community renewable energy projects" [24], "collective action initiatives" [25] to "grassroots energy initiatives" [26] and so on. The development of energy cooperation forms is thereby considered in connection with regulatory frameworks [27], energy systems [28], historical evolution [14], and socio-cultural and economic aspects [16,29]. These factors have shaped various cooperative models among citizens and stakeholders [13,14].

Building on this, the comprehensive systematic review of the recent scientific literature presented here expands our understanding of potential energy cooperation models and integrates lessons from various local energy cooperation projects in Europe. It provides a broad overview of existing and potential forms of cooperative energy initiatives without being limited to specific organisational forms (e.g., cooperatives), legal regulations (e.g., CECs or RECs), or self-designations (e.g., Energy Communities). We use "energy cooperation" as an umbrella term, encompassing *all energy projects that are structured as organisational entities, involve citizens as consumers or prosumers in the planning and/or operation of the project, aim to contribute to the energy transition using decentralised renewable energy technologies, and have some benefit for the community*. To be aligned with the local level defined in RECs and CECs in European regulations, the review gives special attention to forms of energy cooperation that are geographically limited (e.g. to several houses, a neighbourhood, or a municipality) and ideally have positive community effects beyond energy consumption. This specificity formed the basis for the automated literature search, for which a script has been developed (see Methodology Section).

The study has three key objectives: (i) to provide an overview of the energy cooperation terms and concepts used in the literature; (ii) to examine and systematise the various concepts in terms of their differences and similarities in order to gain a deeper understanding of the possible forms of organisation, participants and principles of participation, objectives and motivations, social cohesion factors, economic structures, and benefits and challenges of energy cooperation projects; (iii) to demonstrate a mixed-methods approach to a systematic literature review, combining systematic metadata analysis with narrative-inspired qualitative review. After this introduction in Section one, the paper is structured as follows: Section two presents the methodology of the literature review, and the script search designed for the automated literature search. The main findings are then summarised thematically in Section three (Results) and discussed in Section four. Finally, in Section five, conclusions are presented to derive key findings and to reflect the significance of these findings for the field of cooperative energy projects within the energy transition process.

2. Methodology

The literature search has been carried out systematically based on the SALSA (Search, AppraisaL, Synthesis and Analysis) framework [30]. This methodology determines the search protocols for the systematic literature review and has allowed to narrow down the search to a specific number of keywords, a specific time period (2018–2023), and a specific type of document (see Fig. 1).

The first step, the *search strategy* of the SALSA framework, involved an automated generation of search terms and an automated search in the Web of Science (WOS) database using a script. Three terms ("energy", "community", and "creation") were defined as key for the systematic literature search. For each term a series of keywords was created (see Table 1). The search for references was carried out by creating all possible combinations between the keywords, resulting in a total of 108 keyword combinations.

On this basis, in the *appraisal stage*, we assessed the 920 articles identified. To reduce the scope of the search, two filtering steps were carried out: (i) automatic filtering applied to select articles from journals that rank in quartile 1 according to the Journal Citation Indicator (JCI) reducing the number of articles to 228; (ii) manual revision and selection of articles referring to the European context (including all countries belonging to the European Union during the period considered, as well as those belonging to the European Economic Area (EEA), and the Schengen Area), reducing the number of articles to be analysed to 169.

In the *synthesis stage*, a second manual filter was then applied by analysing the titles and abstracts and selecting the articles dealing with at least one of the dimensions of energy cooperations that we had previously developed based on Hicks & Ison [31] and Kubli & Puranik [32]: energy cooperation concepts, forms and organisational entities, range of participants, level of participation and roles, main purposes and motivations for participation, social cohesion, membership, ownership, vote system, energy production and activities, energy markets, energy benefits, legal framework, or limitations. This reduced the number of articles to 85.

Finally, in the *analysis stage*, the 85 articles were analysed qualitatively in order to identify the different terminologies, as well as types and characteristics of the represented energy cooperations [31–34].

The study was limited by the defined scope of the research (time frame, database, and search terms, as well as the above-mentioned content dimensions), but also by the limitations of the automated research carried out. The timeframe was set for a five-year period between 2018 and 2023, as there was a significant increase in new projects during this period due to the latest European and national energy and environmental strategies. Although the Energy Union Strategy was introduced in 2015, the full adoption of its legislative acts only occurred in 2019 [35]. Additionally, this transition is framed by major European agreements and agendas, such as the European Green Deal, Clean Energy Package, and the REPowerEU Plan [9] which were adopted during the mentioned period.

The database used for the literature search was Web of Science (WOS). Only this database was considered because, among those that have an Application Programming Interface (API), which is a

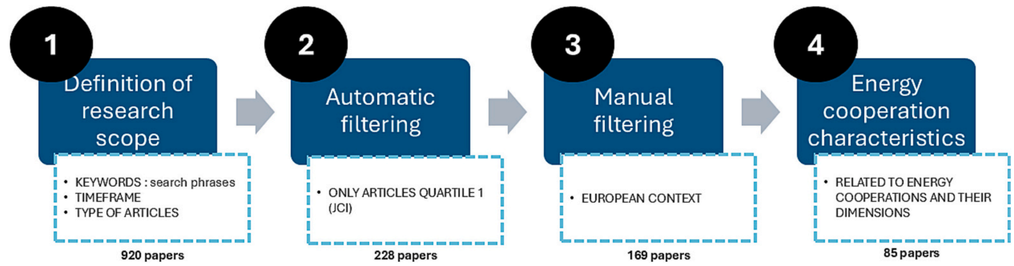

Fig. 1. Steps carried out within the systematic review to narrow the search.

Table 1
Three terms identified for literature review and their associated keywords.

Terms	Keywords
energy_term	["energy", "local energy", "energy production", "renewable energy"]
community_term	["community", "communities", "initiative", "initiatives", "cooperative", "cooperatives", "organisation", "organisations", "cooperation", "cooperations", "form", "forms"]
creation_term	["organisation", "organisations", "participant", "participants", "actor", "actors", "private sector", "public sector", "citizen", "citizens", "civil society", "administration"]

requirement of the script developed, it is a database that has one of the best combinations of request constraints, maximum results, types of analysis, data accuracy and bibliographic information [36]. The search focused on the following types of documents: articles, article early access, editorial material, review, and proceedings paper. It was limited to English language and UK spelling.

3. Results

The results section opens with a targeted analysis of term networks and generalised topics identified through cluster titles. Using VOSviewer [37], the analysis mapped research topics from the 85 papers, creating a term co-occurrence map (Fig. 2) based on titles and abstracts. The analysis was conducted with mostly default parameters from the VOSviewer documentation, with minimal fine-tuning applied. A resolution of 1 and a minimum cluster size of 3 were used to ensure distinct thematic groupings. The map includes 48 binary-counted key terms, with articles sharing zero to one reference excluded. Clusters, distinguished by colour (green, red, blue, yellow, purple), highlight distinct thematic areas. Bubble size reflects term frequency, while the most frequent co-appearances of terms are indicated by connecting lines. Additionally, the distance between bubbles shows how strongly the terms are linked to each other.

Titles were assigned based on the predominant themes and terms in the clusters. The five main clusters identified are: Cluster 1 (red) includes terms related to governance, case-specific actors and case studies, energy poverty, and energy transition, which is the most connective term framing the EU's ambition for climate neutrality. Cluster 2 (green) covers terms associated with policy, development, initiatives, and European countries. Cluster 3 (blue) focuses on community energy initiatives and bottom-up approaches, emphasising the role of local communities in renewable energy adoption. Cluster 4 (yellow) contains terms related to the infrastructure and process involved in renewable energy projects, highlighting the organisational and evolutionary

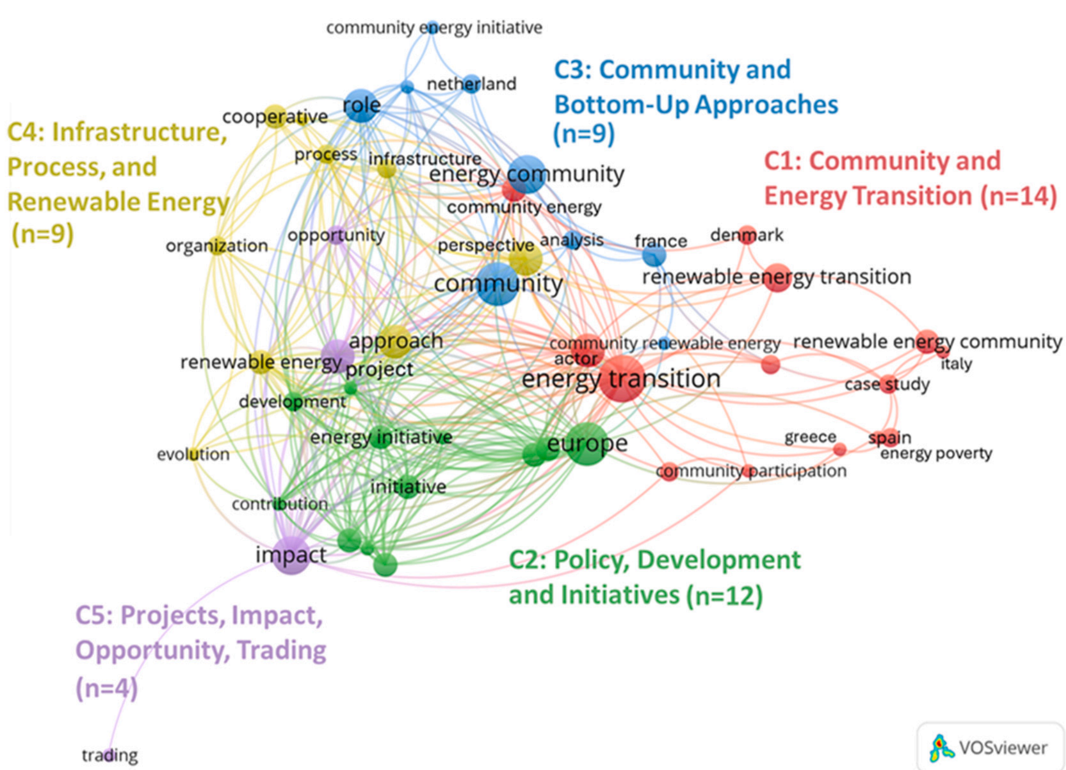

Fig. 2. Network visualisation of title and abstract corpus analysis using VOSviewer.

aspects of energy transitions. Cluster 5 (purple) centers on project, opportunities, trading, and impact - the most connective term, linking to related terms from the other clusters. Despite comprising the fewest terms, this cluster was retained to depict a trading term subgroup of articles focused on energy-sharing and power-trading models, which are positioned as thematic outliers in the visualisation.

After this general overview over terms and clusters used in the literature exploited in the article, the next sections delve into detail. The characteristics of energy cooperations will be analysed summarising their principal elements and range of different alternatives. It should be stressed that the results presented in this section are derived from the literature review, without any personal statement from the authors. In addition, it can be highlighted that most descriptions and concepts – nearly half of the studies in the analysed sample – adopt definitions from existing EU and national policies, as well as literature, relying on established frameworks to contextualise energy cooperations. Approximately one-third of the studies introduce or operationalise new concepts, such as typologies of community-based energy citizenship, showcasing efforts to advance theoretical discourse and propose innovative frameworks. We aim to give an overview over all the concepts identified in the search and to analyse how they converge or differ. Within the following sections key terms of each section are highlighted in bold.

3.1. Broad collective initiative concepts

As a first step, the types of collective initiative concepts used in the literature were analysed. It refers to different organisational structures that are established to carry out collective activities on a certain scale of implementation, on a specific topic, and to achieve particular goals.

When a group of members of a collective defines the basic principles of an organisation (the reasons for its existence, its values and aspirations for the future, etc.), this is usually referred to as **Organisational Identity** (OI) [38]. Depending on its primary goal, collective initiatives may be called by various names, as summarised in Fig. 3 and Table 2. For instance, when multiple stakeholders are driven to achieve a goal that benefits the entire community, it is commonly referred to as a **Community Initiative** (CI) [39]. When they are more growth-oriented and prioritise economic interests, they are usually called **Large Communities of Interest** (LCoI) [40]. And when they focus on a community-based electricity market structure, they are described as **Energy Collectives** (ECs) [41] (Acronym not to be confused with Energy Community, which is often abbreviated in the same way. In this paper, the acronyms EC and ECs are used for Energy Community). **Local Renewable Energy Organisations** (LREOs), in turn, is a term often used for initiatives that are limited to the local level and are linked to renewable energy. Boon [42] defines them as organisations that are initiated and managed by civil society actors and aim to educate people about energy usage and efficiency, or to support them in enabling or facilitating the collective procurement of renewable energy or technologies. As there is no theoretical background or literature describing the development of LREOs, they are considered as an innovative concept. **Community-based Organisations** is yet another related term for civic engagement in the energy sector [26].

Focusing on energy-related initiatives, a rough distinction can be made between initiatives that are local in scope and those that are unspecified. A distinction is also made as to whether the energy initiatives are mainly driven by civil society or by multiple actors. In this sense, the **Local Energy Systems** (LES) are highlighted, deeply embedded within a local context and designed to decarbonise, balance, and coordinate the supply, storage, and demand of energy [43]. Among the energy systems, the **Distributed Energy Systems** (DES) can be highlighted, also called **Distributed Energy Resources** (DERs) [44], which integrate energy production (renewable and not renewable) and methods of energy storage, monitoring, control, and management.

At local level and focusing on energy activities, we can also find terms such as **Local Energy Sharing** (LES), a concept that enables sharing between distribution system participants such as prosumers,

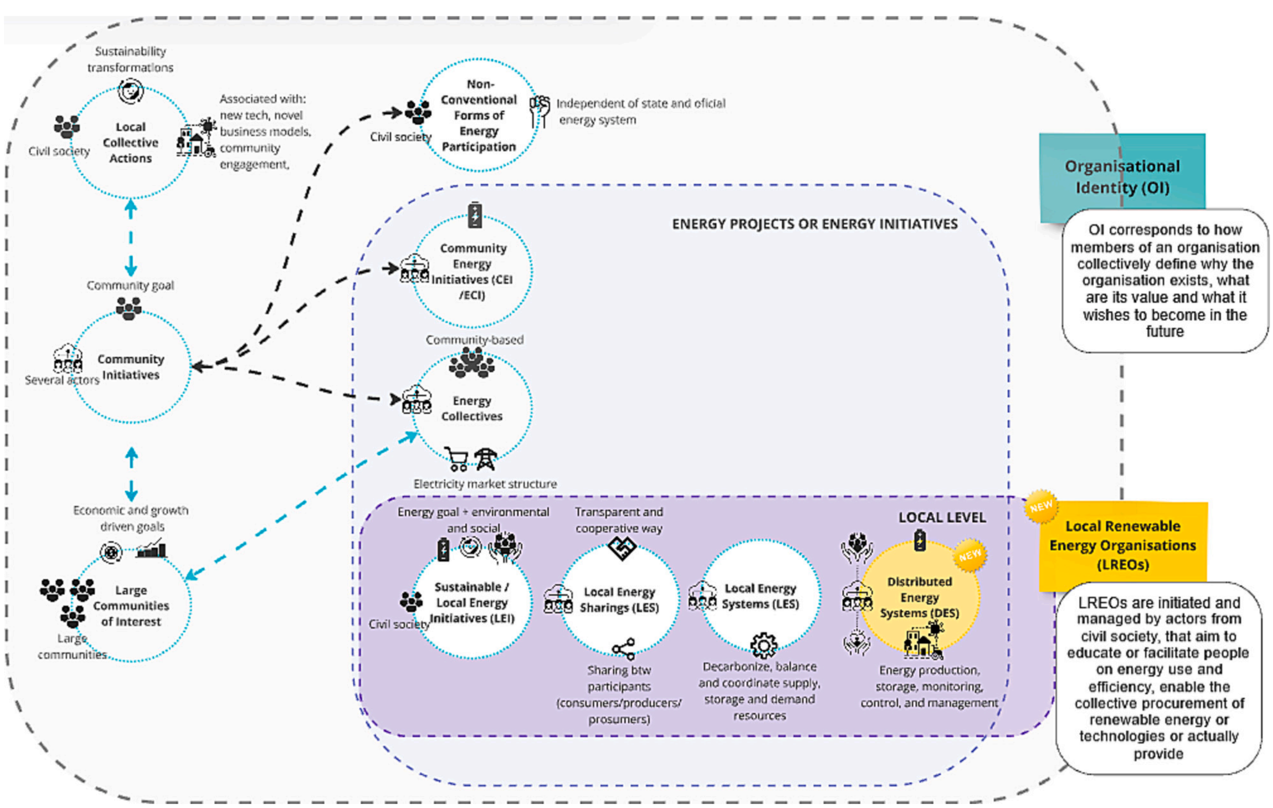

Fig. 3. Scheme of different broad energy cooperation concepts. In orange, new concepts that need further study and development.

Table 2
Summary of characteristics of different broad collective initiatives concepts.

Term	Acronym	Topic	Scale of implementation	Purpose	Main Actors	Ref
Organisational Identity	OI	Multiple	Multiple possibilities	Multiple possibilities.	Multiple possibilities	[38]
Community Initiative	CI	Multiple	Community	Community-wide benefits (unspecified).	Several actors	[39]
(Large) Communities of Interest	(L)CoL	Multiple	Community	Economic values, growth-driven.	Multiple possibilities	[40]
Energy Collectives	EC	Electricity market structure	Community	Community-based electricity market structure.	Several actors	[41]
Local Renewable Energy Organisations	LREOs	Renewable energy	Local	Social (justice, democracy, and self-organisation).	Multiple possibilities	[42]
Local Energy Systems	LES	Energy	Local	Decarbonise, balance, and coordinate supply, storage, and demand resources.	Multiple possibilities (public, private or DNO)	[43]
(Local) Distributed Energy Systems	(L)DES	Energy	Multiple: local (novelty)	Create (local) structures of energy production, storage, monitoring, control, and management, promoting transition to a low-carbon society.	Several actors	[44]
Local Energy Sharing	LES	Energy	Local	Energy sharing between distribution systems participants such as prosumers, consumers, and producers in a transparent and cooperative way.	Several actors	[44,45]
Energy Community Initiatives or Community Energy Initiatives	ECI or CEI	Energy	Community	Energy socio-technical transition, involving innovative organisations and community-based approaches in users' and citizens' involvement.	Several actors	[46]
(Sustainable) Local Energy Initiatives	(S)LEI	Energy	Local	Combine renewable energy production with wider issues such as environmental and social transformation, and a specific quest for civic participation, building on local knowledge and networks, and developing solutions appropriate to local contexts.	Civil society	[26,39,47]
Non-institutional or non-conventional forms of energy participation		Energy	Local	Ambition of being independent of the state and the official energy system. Citizens try to directly decide about the fate of energy transition, organising themselves around energy issues, generating energy and influencing the methods and sources of energy production.	Civil Society	[26]
Local Collectives Actions	LCA	Energy/ Sustainability	Local	Sustainability transformations. Associated with new technology, novel business models and community engagement.	Civil Society	[47]

consumers, and producers in a transparent and cooperative way [44,45]. In the context of Community Initiatives, the **Energy Community Initiatives** or **Community Energy Initiatives** (ECI or CEI) can be highlighted, which involve a variety of actors, energy technologies and different degrees of community participation [46]. Also, at local level but managed or financed directly by actors of the civil society, there are the (**Sustainable**) **Local Energy Initiatives** (SLEI or LEI) that combine renewable energy production with wider issues such as environmental and social transformation, and a specific quest for civic participation, building on local knowledge and networks, and developing solutions appropriate to local contexts [26,39,47]. When these initiatives have the ambition to remain independent of state and the official energy system, they may also be called **non-institutional or non-conventional forms of energy participation** [26]. Finally, **Local Collectives Actions** (LCA) can be also highlighted. With a civil society engagement, and focused on sustainability transformations, they are associated with the adoption of new technologies, implementing novel business models focusing on locally generated electricity, and community engagement approaches [47].

3.2. Organisational forms and entities of energy initiatives

Different types of organisational forms, with or without legal form, emerge around energy initiatives. The results of the literature review were classified as proposed by Horstink et al., according to their focus: self-focused, civic-focused and prosumer-focused [48].

Self-focused is used for those organisational forms in which the main objective is the benefit of the entity itself. In other words, prosumerism is not their main activity, but a means to achieve energy self-sufficiency and contribute to other secondary objectives such as, for example, environmental ones [48]. In this category, **Collectives of Self-Consumption** (CSC) can be highlighted [11,49], in which participants have a high level of autarchy from the grid (they consume the energy they produce and the excess is fed into the grid) [49]. It can be differentiated between individual self-consumers (single family buildings) and jointly acting renewable self-consumers (e.g. apartment building). Depending on the sector to which the prosumers belong, it is possible to differentiate between **business**, **non-profit**, and **public self-focused**.

Energy initiatives are considered **civic-focused** if they benefit the community, have a highly participatory governance structure, and are driven by societal, environmental and/or community purposes [48]. Within this category, the best-known organisational form are the **Energy Communities** (ECs) [26,40,50–52], which are considered bottom-up collectives that aim to create benefits for their members through energy-related activities that correspond with the members' interests, values, and needs [40]. They involve groups of citizens, social entrepreneurs, public authorities, or community organisations who participate directly in the energy transition by jointly investing in, producing, selling, and distributing renewable energy [52]. They are considered to be non-commercial market actors. They are called differently depending on their location, the type of energy, the way they were initiated, their governance, and their main goals (see Fig. 4). When the beneficiary is the local community, they are called **Local Energy Communities** (LECs) [53]. Some scholars have further differentiated them in **Formal Energy Communities, Informal Energy Communities**, and **Neighbourhood Energy Communities** [48]. If they are not tied to a local context, transcending geographical borders, they are called **Virtual Energy Communities** [48]. On the other hand, those energy communities that specifically focus on renewable energy are designated as **Renewable Energy Communities** or **Community Renewable Energy**

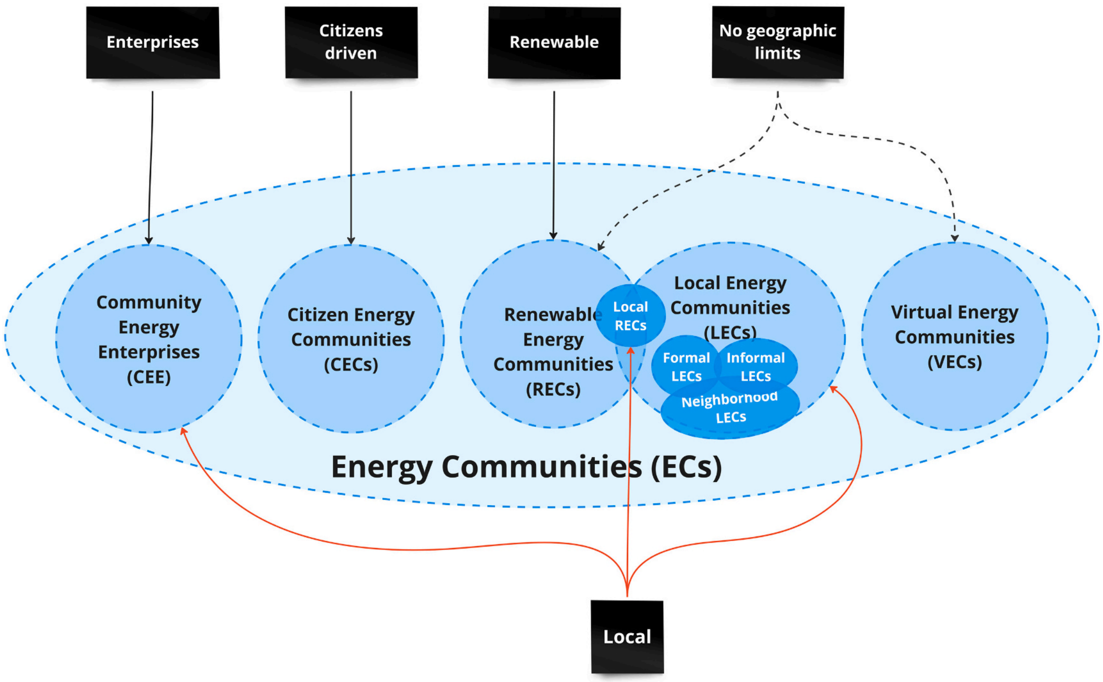

Fig. 4. Types of energy communities.

(RECs or CREs) [10,54]. Furthermore, they are considered **Citizen Energy Communities** (CECs) when they are citizen-driven [55]. This means that it is managed effectively by members or shareholders, which are not related with the energy sector as main economic activity [54]. They are also known as **Energy Citizenship**, **Civic Energy**, **Grassroots Energy**, or **Community-based Organisations** [26]. According to European legislations, both Renewable Energy Communities (RECs) and Citizen Energy Communities (CECs) are forms of Energy Communities (ECs) and are considered non-commercial market actors [11].

If the governance model is based on the cooperative concept, they are called **Energy Cooperatives** [26,51,56–58]. Within this category, depending on their focus, a distinction can be made between **Renewable Energy Sources Cooperatives** (RES-Co-ops) [59] or **Renewable Energy Cooperatives** (RE-Co-ops) [60], and **Civic Energy Cooperatives** (CECo-ops) [48]. It is also possible to have different types of cooperatives depending on the topic and type of members, highlighting **Housing cooperatives** and **associations**, **Sustainable mobility cooperatives** and **Historic rural electrification cooperatives** [51].

Prosumer-focused are those energy initiatives that focus on the process of prosumerism itself, willing to facilitate, influence, or benefit from prosumers and the phenomenon of prosumerism [48]. In this group, several forms of organisation are considered in the literature, such as **self-organised energy groups** that are formed with the aim of matching supply and demand and sharing local resources. Their role in energy systems can be further emphasised by giving owners the power to manage their sources as they wish (how and to whom to distribute it) [61]. Related to it, in Poland, for example, **energy clusters** were developed, which are defined as "*a civil law agreement, which may include natural persons, legal persons, scientific units, research institutes or local government units, and which pertains to the generation and balancing of demand, distribution or turnover of energy from renewable sources, or other sources or fuels, within a distribution network with a rated voltage of less than 110 kV*" [62]. They aim to secure local energy resources, which affects meeting sustainable objectives of a nationally owned global economy [63]. Unfortunately, civic involvement in these energy projects is rather limited [58]. Due to their objectives, energy groups and energy clusters can be considered prosumer-focused with a tendency to civic-focused actions.

Another term found in the literature is **Community Energy Enterprises** (CEE), with the goal to "*create collective business ventures and, through them or their results, to aim to contribute to both local economic, and social development*" [46] among the wider local community. The ownership in these cases is shared between local-based individuals (or shareholders) and the enterprise that promotes the participatory process and support investments in local energy projects. Other concepts that arise are the **Eco-villages** or **Bioenergy villages** [50] which are "*community-led-bottom-up initiatives that organise and finance the implementation of their own local heat supply grid that supplies households with heat produced from biomass*" [64]. These forms could also be considered as prosumer and civic-focused.

As a novelty, some scholars propose to create **Hybrid Solutions**, forming partnerships between local authorities, energy intermediaries and local energy networks [65]. These alliances, for example, allow energy cooperatives to act more professionally and have the possibility to operate in business and market-oriented ways, being also able to scale up projects [66]. All these terms are summarised by topic and level of focus in Table 3.

The most widespread and commonly used organisational terms are **Energy Communities**, **Energy Cooperatives**, and **Energy Citizenship**. This is evidenced by the number of papers addressing each term. Data on energy communities were collected from 24 of the 85 papers analysed. This is followed by Energy Cooperatives, with 13 papers discussing this type of entity. Only six papers provided specific information on Energy Citizenship. Other terms such us Bioenergy Villages, Collective Self-consumption, or Energy Clusters, were only discussed in two papers and, in the case of Energy Groups only one paper. The novelty of the Hybrid Solutions is also only addressed in two papers.

3.3. Range of participants, level of participation, and roles

An important element of the various forms of energy cooperations is the wide range of actors, roles, and modes of engagement present in different energy initiatives. The participants of an energy initiative can be categorised individually or collectively as **consumers** (consume the energy), **producers** (produce the energy), **or prosumers** (produce and consume the energy) [50,67]. They can belong to any sector: non-profit

Table 3
Summary of organisational forms depending on the main topic and level of focus.

	Organisational form		Main topic							Level of focus			Refs
			Building	Local	No geographical limits	Multistakeholders	Citizens-driven	Cooperative	Renewable energy	Self-focused	Prosumer focused	Civic focused	
Self-consumption	Collective Self-consumption (CSC)	Self-focussed: Non Profit Sector	■							■		■	[11, 49]
		Self-focussed: Public	■							■		■	
		Self-focussed: Business	■							■		■	
Energy Communities	Local Energy Communities (LECs)	Informal EC		■								■	[53]
		Formal EC		■								■	
		Neighborhood EC		■								■	
	Community Energy Enterprise (CEE)			■							■	■	[46]
	Renewable Energy Community (RECs / CREs)					■			■			■	[10, 54]
	Virtual Energy Communities (VECs)				■							■	[48]
	Energy Communities (ECs)					■						■	[26, 40, 50–52]
	Citizens Energy Communities (CEC)						■					■	[55]
	Hybrid solutions (i.e: EC/ECoop + CEE)			■		■		■	■		■	■	[65]
Energy collectives	Self-organised Energy Groups			■		■					■	■	[61]
	Energy Cluster				■	■					■	■	[63]
Energy Cooperatives	Civic Energy Cooperatives (CECo-ops)						■					■	[48]
	Energy Cooperatives (ECo-ops)					■		■				■	[26, 51, 56–58]
	Renewable Energy Sources Cooperatives (RES-Co-ops)							■	■			■	[59]
	Renewable Energy Cooperatives (RE-Co-ops)							■	■			■	[60]
Eco-villages	Bioenergy or Eco-villages					■			■			■	[50]

The shaded cells indicate the topics and level of focus that apply to each one.

(foundations, NGO's, associations, etc.), public (schools, universities, retirement homes, hospitals, institutes of public authorities, etc.), business (companies in industry, services, agriculture, etc.) or property sector (social real estate projects, homeowner or tenant associations, municipal real estate energy schemes, or district heating projects, etc.) [48]. Table 4 summarises the key actors, roles, and engagement modes in various energy initiatives, highlighting participants' responsibilities and the importance of intermediaries and lobbying activities.

As shown in Table 4, there are various participants and roles integral to success and often found in various entities. These include groups of **citizens**, **consumers**, **social entrepreneurs**, **energy suppliers**, **keystone players** (lead firms) or **ecosystem captains**, and **community organisations**. These entities participate directly in the energy transition by jointly investing in, producing, selling, and distributing renewable energy. The role of **intermediaries** [41,65,72,74,75] is frequently emphasised together with experts (including technical, legal, economic, and political experts, for example, from universities) [69]. They act as trusted agents and catalysts [72,76], providing services that centralise and disseminate information to ensure ecosystem access for all stakeholders, thereby accelerating the definition of a local ecosystem [52]. Additionally, **lobbies** play a crucial role in shaping (supra)national policies to create a tangible business case for these projects, with lobbying activities often conducted by associations or NGOs, such as Rescoop at the EU level [48,52]. **Core members or shareholders** of the community can include individuals, small and medium-sized enterprises, local authorities, or municipal governments [68]. In the context of Renewable Energy Communities for companies, other significant participants emerge, such as **energy cooperatives**, **electricity providers**, and **energy experts** [60]. Furthermore, in Community Energy Initiatives, particularly for local and sustainable heating, Van der Schoor and Van der Windt highlight the importance of intermediaries within external network and material dimensions [68]. Considering the material dimension, including technical and bio-physical factors, crucial in determining the most appropriate organisational form, as well as its scope, the activities that will be carried out, and the potential limitations it may face.

3.4. Main purposes and motivations for participation and involvement

Throughout the literature reviewed, different motivations are discussed that encourage participants to take part in the different emerging energy initiatives (see Fig. 5). As reflected in the main objectives of the different energy initiatives, the most frequently cited motivations at the overall level are **social**, **economic**, and **environmental** reasons. Issues

Table 4
Summary of key actors, roles, and modes of engagement in energy initiatives.

Category	Conceptual differentiation	Specific roles	Dimensions/responsibilities	Refs
Energy Communities (*in general*)	Citizens and Consumers	Joint investors, producers, sellers, and distributors	Actively engage in energy transition; provide financial resources, labour, and participation.	[52]
	Social Entrepreneurs	Initiators and leaders of community energy projects	Drive innovation; create community-aligned business models; mobilise resources and support.	
	Energy Suppliers	Providers of technical expertise, infrastructure, financial resources	Ensure reliable energy supply; integrate renewable energy sources; maintain energy systems.	
	Keystone Players/ Ecosystem Captains	Lead firms or central organisations	Coordinate activities; provide strategic direction; ensure ecosystem cohesion.	
	Community Organisations	Local groups or associations	Facilitate community engagement; manage resources; ensure equitable benefit distribution.	
	Intermediaries	Trusted agents and catalysts	Centralise and disseminate information; enhance access to the ecosystem; accelerate local project growth.	
	Lobbies	Influencers of policy and regulatory environments	Shape (supra)national policies; conduct lobbying activities (e.g., by associations like Rescoop at EU level).	
Community Energy Initiatives	Internal network	Core-network	Deals with organisational issue.	[10,68]
		Nearby social network	Concentrates on fostering citizen participation.	
	External network	Public parties	Consisting of public parties focusing primarily on municipalisation issues.	
		Private parties	Offer cooperation and technical expertise.	
	Material dimension	Technical factors	Technical options and choices.	
		Bio-physical environment	Physical and spatial conditions.	
Renewable Energy Communities (REC)	Core Members	Leader, community manager, or identity manager	Facilitates the achievement of a community's mission and vision, monitors community engagement, communicates, moderates, and gives advice, as well as disseminates the community's culture (related to awareness of the relevance of energy) and knowledge in the topic.	[10,38]
		Advisory area	Responsible for community engagement.	
		Tactical area	Contributes to realising the required activities to achieve the RECs objectives.	
		Strategic area	Supervises prioritisation, defines best practices for achieving objectives, exercises control, and reports directly to the members for retrospective analysis.	
		Board of directors	Act as facilitator and mediator, while also ensuring that REC progresses in accordance with the agreement among members.	
	Periphery Members	Intermediaries	Act as facilitators at political, administrative, and social levels.	[69]
		Experts	Including technical, legal, economic, and political experts, for example, universities.	
		Community creator	Primarily focused on setting up the community and on engaging citizens.	
		Founder, and owner	Focus on establishing of the community.	
Local Energy Communities (LECs)		Entity manager designated as collective self-consumption management entity	Ensure the commercial relationships.	[70]
			Establish contracts with market participants or facilitators for surplus sales, supplying contracts for electricity deficit.	
			Exchange the collective self-produced electricity, revenues, and costs according to LECs statutes.	
Community Energy Enterprises (CEE)	Local Authorities (LA)	Providers	Provide spatial and financial assets in order to assure the technical feasibility of the electricity production plant.	[46]
	Community of Investors (CoI)	Investors	Composed by the group of citizens which have invested in the selected CEEs.	
	Project Manager (PM)	Manager	Key stakeholder for technical, financial and engagement competences.	
	Local Organisations (LO)	Facilitators	Facilitate community engagement, support communication and the implementation of the project and its organisational features.	
Renewable Energy Resources (RES)	Prosumer influencers	Developers and technical service providers	Help set up prosumer projects; offer technical services; play an influential role in RES development (for example local, regional, national, and EU authorities; energy agencies; energy funds; and energy lobby groups).	[48]
	Prosumer facilitators	Non-profit service providers	Offer services on a non-profit basis in order to support prosumers.	
Sustainable Distributed Energy Systems (DES)	Add value providers	Smart building or microgrid operators, data services companies, etc.	Add value to resources that will be used by other actors.	[71]
	Resource providers	Energy equipment vendors, landowners, etc.	Offer energy assets to other actors.	
	Load operators	Responsible for power consumption	E.g.: manage energy use in households; municipal, commercial, and industrial facilities' energy use.	
	Network value actors	Serve as connectors among customers, objects, and locations	Operate electric and gas distribution systems; manage virtual plants.	
	Community actors	Responsible for the local area covered by the DES	Oversee and ensure the sustainability and functionality of local energy systems.	
	Intermediaries	Systemic	Operate "*in networks instead of* '*one to one*' *mediation*" and carry out systemic functions, such as articulating needs and opportunities, assistance in learning process and, matching stakeholders and options.	[72]
		Niche	Work to experiment and develop the activities of a particular niche, as well as in the socio-technical enhancement of that niche.	
		Regime-based transition	Promote the transition, it is linked, for example, through agreements or institutional interests, to the sociotechnical mainstream and interacts (frequently) with a set of niches or with the whole system.	

(*continued on next page*)

Table 4 (*continued*)

Category	Conceptual differentiation	Specific roles	Dimensions/responsibilities	Refs
		Resource providers	Offer energy assets to other actors (for example energy equipment vendors, landowners).	
		Load operators	Responsible for power consumption (for example household consumers, municipal/commercial/industrial facilities, etc.).	
		Network value actors	Serve as connectors among customers, objects, and locations, facilitating exchange (for example electric and gas distribution system operators, virtual plants, etc.).	
		Users	Make the link between new niche technologies and users and between the preferences of users and the developers and agents or actors involved (for example, smart building or microgrid operators, data services companies, etc.).	[73]

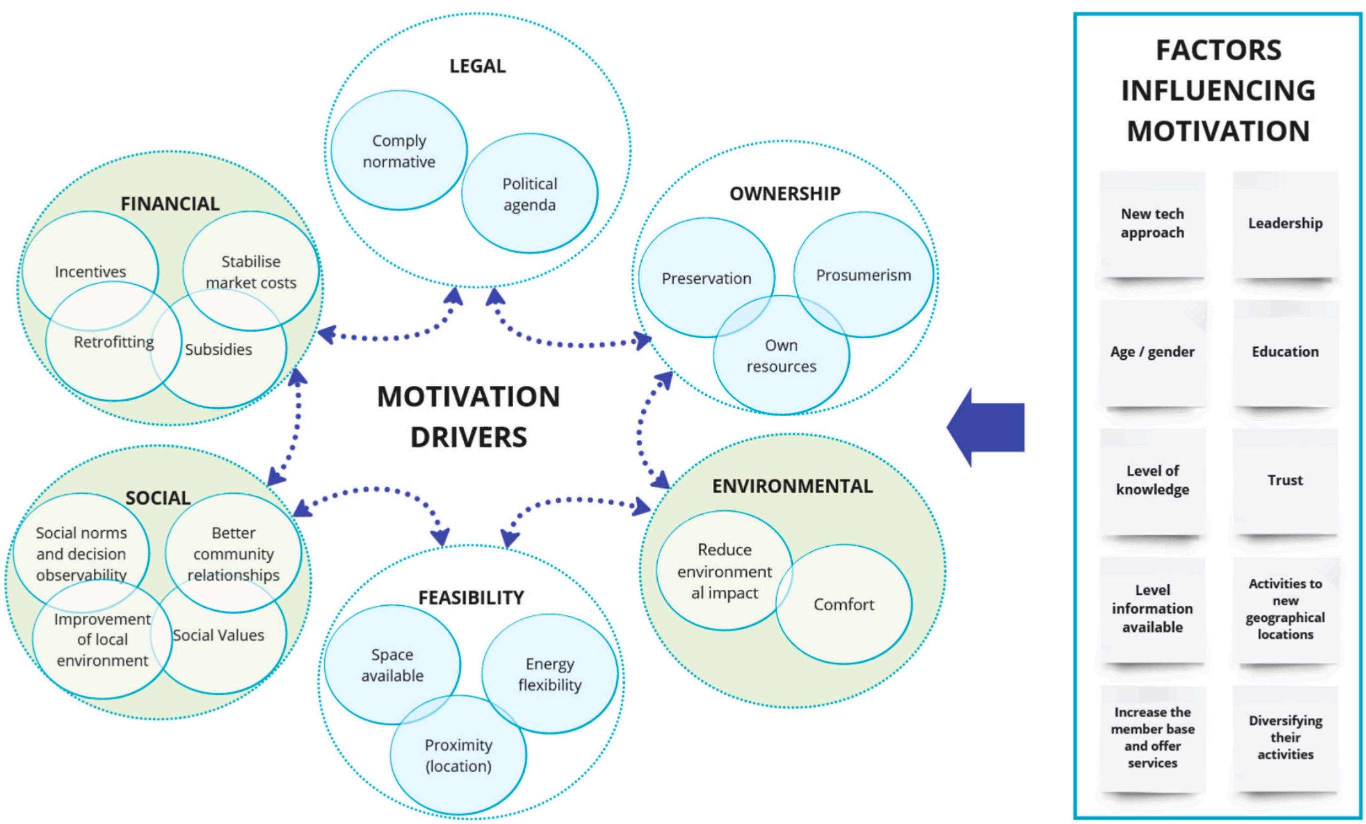

Fig. 5. Main motivation drivers for actors to be engaged (in green the most common are highlighted) and factors that influence these motivations. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

that, for example, Energy Communities [50,77], both Renewable Energy Communities and Citizen Energy Communities [54] and Local Energy Initiatives [26], consider as main focus. It may be noted that Large Communities of Interest tend to pursue more economic values [40], and Small Local Communities – most of the Local Energy Cooperatives and Local Energy Initiatives – focus more on environmental and social issues [40,48]. Local Energy Communities also aim to maintain supply and reduce energy poverty [53]. Other important motivations are **legal** [38], **feasibility** [78], and **ownership issues** [52,79].

Among social motivations, **social norms** (such as pro-environmental attitudes) and **decision observability** (for example, social pressure to act in accordance with the expectations of peers, or influence of neighbour's actions) can be highlighted as motivations for people to support renewable energy [38,80,81]. Other social motivations to be noted are **social values** [54,59], such as the wish to support initiatives one cares for [56] or altruistic inclinations [82] (the desire to support the community; being part of something that transcends the personal household) [38]. Agents' social motivations can be also related to the search of a **better local environment** and the **improvement of community relationships** [46].

In the context of **environmental motivations**, stakeholders seek to **reduce the environmental impact** that human actions cause [38,39] through, for example, the use of renewable energies [69]. Also, by protecting the environment, they aim to **improve their living conditions and comfort** [83].

Financial motivations are mainly linked to **economic incentives** and **fiscal measures** [84] such as participatory bonuses to promote local renewable projects [57], specific bonds offered by municipal governments to investors, tax reliefs, or on-bill finance [85], discounts to some fixed taxes of the variable term of the electricity tariff [10,86], or feed-in tariffs (FITs) [52,54]. They may also be linked to **financial retrofitting** obtained from energy produced [38,56,59,69,79,86–88], as well as to savings on electricity bills [46] and the possibility to be active market players, participating in spot and derivatives markets, but also negotiating private bilateral contracts [86]. Sokołowski [54] emphasises that Renewable Energy Communities and Citizen Energy Communities look for financial benefits rather than financial profits. **Subsides** and **public funds** are also highlighted in the literature as attractive for different actors [85].

Regarding legal issues, there are two main motivational factors. From one side, there is the desire of **complying normative**, wanting to act ethically and morally with the European or national environmental strategies and agendas [38]. On the other side, some actors such as energy agencies or energy lobby groups, want to support the development and implementation of the **political agenda** [48].

Within the realm of **feasibility, proximity** can be considered a motivational factor since people are more willing to invest if the renewable energy installation is close to their homes [79]. **Space** is also an important factor, not only **surface availability** (enough space for producing the needed energy) [78], but also the feeling of **place attachment** (belonging to a particular geographical area) is highlighted as a key factor in social acceptance by local communities [89]. Further factors related to feasibility motivations which are discussed in the literature are **local flexibility**, **balancing**, and **system integration** [43].

Regarding ownership motivations, the concept of **materialistic ownership** can be highlighted [52] ('from us for us' and 'from our own ground'). This is related to the interest of the stakeholders in their own material payoff (for example, the fact of getting a return on investment or the reduction of their energy bill), on protecting or increasing their own resources, the willingness of **prosumerism** [47,48] and/or looking at **preserving the energy cooperation** development [38]. These types of motivation usually lead to the creation of a community-owned legal entity.

Other factors identified as influencing stakeholder participation include **leadership** and **trust** [82,88], that means having confidence that one's vulnerabilities will not be exploited by others [39], and that leaders are trustworthy [38]. Additionally, a person's **background** and **characteristics** – such as, for example, age, gender, level of education, or place of residence - have been recognised as factors that influence levels of participation. Younger, better educated, and wealthier people are more likely to take an active role than older and less educated individuals [78]. The level of participation is also related to gender issues. Males are more engaged with energy projects, and they are mainly motivated by financial returns. In the opposite way, women, whose role has been recognised as important on leading energy transition, are more interested in nonprofit projects [57]. Likewise, the **level of available knowledge** and **information** can boost motivation for participation. For this purpose, it is important that people driving the initiatives find a way to produce diverse documents tailored for both households and professionals in order to help them to understand and be engaged in the initiative. Some ways to do so are: training and education programs, reports and guidelines, or sharing information on the results obtained (energy production, consumption, etc.) [38]. Finally, it is noted that certain participants may be intrigued by activities that explore **new practices** and/or **technical advancements** [38].

It was also observed that certain factors can enhance participation levels, such as expanding **activities to nearby geographical locations**, focusing on replication by others (becoming exemplary), **increasing the member base** and **offering services**, as well as **diversifying activities** to broaden the range of products or services provided [38].

Regarding engagement levels in the European Union (EU), Panarello and Gatto [4] report that actors in Southern Europe are less inclined to adopt renewable energy solutions as they are latecomers in the EU and, thus, remain poorly integrated with EU energy policies, socioeconomic, and environmental strategies. Similarly, in Eastern Europe, despite longer EU membership, economic stagnation has hindered social engagement. There is a need for energy policies that can improve this situation. In contrast, Northern and Western member states of the EU tend to exhibit a green attitude and are more receptive to renewable energy advancement. They have adapted their energy policies more effectively, taking the lead in this process.

3.5. Social cohesion

It was detected throughout the literature review that there are certain factors that promote social cohesion of the actors involved in energy cooperations. Some of these factors coincide with some of the main motivations for being engaged in the initiatives discussed above.

In community-based groups, establishing an **engaged** community is essential [90]. This requires that the actors involved must be **cooperative** and **active** in carrying out necessary activities. It is suggested to include representation from the **quadruple helix** (academia, citizens, private sector and public administration) [10]. **Networking activities** – such as sharing platforms or events to create networks of energy community members – are highlighted as a means to create solid social interactions both between different energy initiatives and between community members [52,91]. The level of participation also hinges on the **knowledge** and **skills available** within the community [90]. The implementation of Energy Information Offices, the so-called **one-stop-shops** (OSS), are proposed as a solution to equip individuals with the essential skills and knowledge for home-energy refurbishment [85]. Additionally, offering **training programs** or **information campaigns** to local actors can raise awareness for the energy transition process and enable them to make well-informed decisions regarding the adoption of energy efficiency measures [10,52,54,65,82,85,90]. Mutual **trust** is considered another key element [10,76]. Enhancing trust can be achieved by having neutral entities like public authorities and landlord/tenant associations which provide lists of trusted and reputable professionals, thereby addressing market **transparency** issues [85]. The relationship between communities can also be strengthened by the adaptation of **collective business models** [72]. **Smart contracts** with **blockchain solutions** are notable ways for enabling participants to cooperatively work towards a decarbonised electrical grid, jointly deciding on a local optimisation process that minimises the overall aggregated cost [87,92].

It is also noted that **ownership** enhances social cohesion and responsibility, fostering participation in decision-making processes [50]. Likewise, **democratising energy** can act as a catalyst for social transformations and technological innovations (Fig. 6) [10].

3.6. Membership, ownership, and voting system

Participation should be **open** and **voluntary**, as outlined in Renewable Energy Communities (RECs) and Community Energy Enterprises (CEEs) [54,81]. It should be accessible to all potential local members based on **non-discriminatory** criteria, ensuring proper **division of roles** between professional economic actors and civic engagement, with a **broad participation** of all stakeholders [10,54,82].

Despite the main principals of participation, the ownership among the different members can be categorised as **distant** or **local ownership**, depending on whether the owners live or develop their main economic activity outside or inside the area where the energy infrastructure is located [7,108]. Ownership can be **inclusive** or **exclusive**, depending on whether all citizens within a predetermined area have an equal chance to benefit from the energy project or the project promoters choose to limit benefits to a selected group, excluding others [93]. Furthermore, ownership is deemed **autonomous** when no single shareholder can own more than 33 % of the shares [81]. For **collective** and **individual prosumption**, ownership of at least 50 % of the production rights by the legal entity is a criterion [50]. Lastly, ownership is considered **hybrid** or **mixed** when various stakeholders (local, corporate, and governmental) engage, compete, and collaborate towards shared goals [93].

The literature review identified the following voting models: the most prevalent is the cooperative system, which operates on a **one-person-one-vote** basis [48,52,60], but other possibilities include voting rights **proportional to shares** [81], the **multi-stakeholder model**, or **collaborative governance models** where decisions are reached by

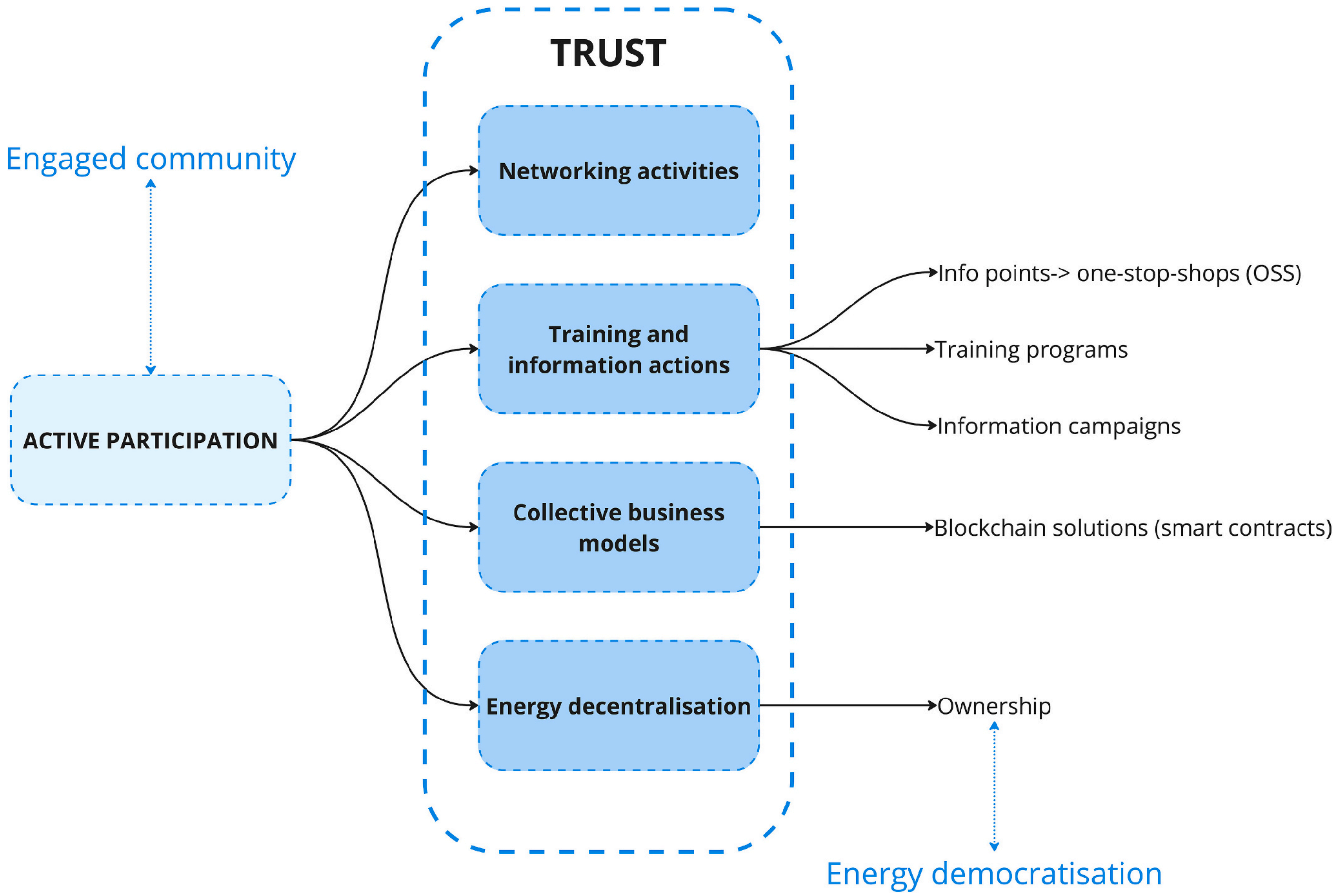

Fig. 6. Scheme of factors that influence social cohesion.

consensus, built from the information provided by all parties involved [10].

3.7. Financing in creation and operational stages

To initiate energy cooperations, securing initial capital for establishment is essential. Various mechanisms exist to acquire this capital (Fig. 7). **Public subsidies** are common, setting up funds for the developmental phase of energy-community projects, which may cover all or part of loan expenses [50,52,54]. Another possibility is **public financing**, when municipal governments issue **specific bonds** to finance energy efficiency retrofit for investors. These loans can usually be repaid over a set term, typically 15 or 20 years, through an annual charge on the property's tax bill, or by encouraging **private finance solutions** like **on-bill finance** or **feed-in-tariff** [50,85]. In the Netherlands, for example, public support is combined with financial aid from traditional entities such as Distribution System Operators (DSOs) and energy suppliers [52]. Some scholars point out that member states could, for example, provide RECs with dedicated **credits with preferential terms,** including low interest rates [54,85]. Also, forming local energy networks can facilitate access to finance and funding [65]. **Private or public investments** are another common mechanism [52,60,79,81]. **Crowdfunding platforms** are highlighted as an innovative way to gather funds for small or medium-scale renewable projects, enabling developers to collect investments from a broad spectrum of investors through various financial participation options, such as donations, lending, or purchasing equity/community shares [52,57,58]. This is considered to have the potential to bridge the financing gap in the energy transition due to its ability to connect numerous potential small investors with shared interests [56]. Another private investment approach involves an **initial capital contribution** based on leverage [69,79,81], where low share price usually facilitates entry [38].

The most common activities conducted by energy cooperations include **investing** in, **producing**, **consuming**, **storing**, **selling**, or **trading**, and **distributing** renewable energy [40,65,94]. Schwanitz et al. [51] outline that the most widely used energy sources, ranked from most to least utilised, are **photovoltaic systems**, **wind parks**, **biomass-based systems**, and **hydropower**. Other less common resources include **solar thermal**, **concentrated solar power**, **geothermal**, and **hydrogen** production. Literature reveals various energy initiatives that utilise multiple energy sources.

The above mentioned activities are typical within Energy Communities (ECs) and Energy Cooperatives (ECo-op) [52,92]. They may also engage in **various market products** to **trade electricity** or **provide flexibility** [86]. As commented by Algarvio [86], ECs could be active market players and negotiate private bilateral contracts. Moreover, they have the potential to participate in secondary services, assisting system operators in balancing the power system and preventing grid congestion.

Regarding the surplus energy that energy cooperations do not consume, there are multiple possibilities. On the one hand, it can be **stored** using **Community Energy Storage System** (CESS) and **local batteries** [49]. Another way to store energy can be through **thermal energy storage** used in **Concentrated Solar Power** (CSP) systems, which are still being developed and require further exploration [95]. On the other hand, actors can **sell power surplus** to the **power grid** at the feed-in tariff or pool price [49], or they sell it **among local actors** with negotiated payoffs (for example, prosumers selling surplus to ECs [67]). It is also possible to create **cooperative alliances** between different types of energy initiatives [96]. In this context, two different business

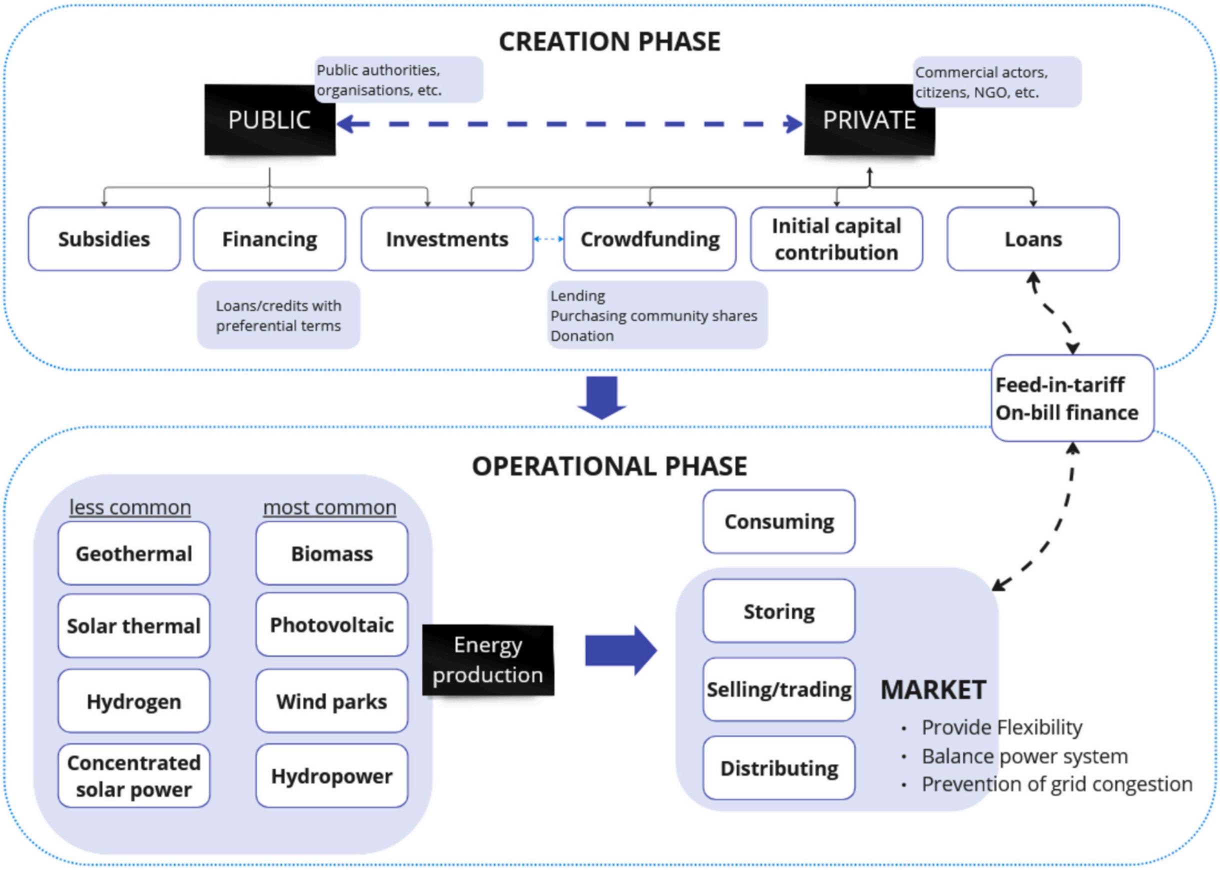

Fig. 7. Scheme of possible financing systems to support energy cooperations within the framework of their creation and operational phase.

models emerge for the so-called **physical storage rights** (PSRs): market participants offer part of their unused storage, or storage is exclusively supplied by an external entity that profits by selling storage services solely in the form of PSRs [94].

3.8. Energy markets

Energy initiatives aiming to disconnect from the **traditional energy market**, where agents purchase electricity from the power grid at industrial prices [96], still encounter severe stability challenges at all times [92]. Power systems with increasing levels of Variable Renewable Energy Sources (VRES) add unpredictability to the net load. Nevertheless, with the complementary use of ancillary services, system stability could be ensured. To confront this issue, it is essential to achieve greater **energy flexibility** [86]. Information and Communication Technology-enabled platforms **(ICT-enabled platforms)** can provide the necessary functionality to mitigate power outages and enhance power system resilience [61], thereby facilitating the creation of an **energy network** [52]. Energy could be then supplied, for example, from **micro smart grids**, which include mini power plants, photovoltaic systems, and/or biogas plants, all interconnected through ICT instead of the current centralised sources system [88].

Moreover, the deployment of automated **Home Energy Management Systems** (HEMS) can regulate energy consumption in households, buildings, or businesses to devise the optimal strategy for reduction by scheduling appliances' operation (independent model) or by participating in a **Local Energy Market** (LEM) (integrated model) [53,70]. In LEMs, users can trade energy and balance the power system between demand and supply in a competitive market. These are also called **Community-based electricity markets** [41,70]. Buildings are associated to it to facilitate collective self-consumption [11]. Broadly, these markets serve as platforms for trading activities and fostering interactions between Local Energy Communities (LECs) and external systems operators, such as retailers and Distribution System Operators (DSO) [70]. Within LEMs, energy trading can be conducted using any of the three **Peer to Peer** (P2P) market models [49]: **centralised**, **decentralised**, or **hybrid** [97]. All of which are currently in the early stages of development [57]. A centralised market involves an aggregator who gathers data (such as charging and discharging demand) and manages the operation of **Distributed Energy Resources** (DERs), making decisions about devices (allocation of energy) to achieve a common goal, like, for example, maximising financial benefits. In a decentralised market, there is no intermediary; peers directly engage in energy trading and price negotiation through bilateral contracts. P2P trading not only benefits the participants but also reduces the charging load on the grid [97]. **Hybrid markets** are a combination of decentralised and centralised markets. An aggregator supervises transaction activities, but peers control their devices and pursue their own interests. These markets employ different pricing mechanisms, such as bill sharing, mid-market rates, auction-based pricing strategies, or multi-class energy management. The latter involves a distributed, price-directed optimisation mechanism designed to satisfy prosumer preferences and optimise external costs ([97]). Furthermore, Goitia-Zabaleta et al. [49] discuss two different P2P models: the **Full P2P** (F-P2P), where energy trading occurs between buildings and users bid in a first price sealed-bid fashion according to their individual preferences, and the **Community-based P2P** (C-P2P), which is a centralised approach of P2P aiming for collective benefits. The latter is identified as the most appropriate model for maximising locally generated energy. In this case, P2P energy trading platforms are integrated into smart grids and typically depend on information and communication technology. Small prosumers can sell energy surplus to consumers within the same network who seek more affordable green electricity compared to the central grid [57] (see Fig. 8).

Cutsem et al. [98] discuss two system designs for the interaction between the grid, prosumers, and Renewable Energy Sources (RES), as presented in Fig. 9: Scheme of centralised aggregator approach and autonomous decentralised approach [92]: **centralised aggregator approach** and **autonomous decentralised approach.** The former centralises communication with the grid operator and aggregates flexible building parameters and RES data to optimise a specific goal during both planning and real-time operations. The latter, however, does not require a central entity to supervise all data. It consists of Smart-Buildings and heterogeneous RES, capable of autonomously managing data and consuming energy in a smarter way, facilitated by smart contracts. In the context of energy trading markets, the concept of **power-profile trade** is gaining prominence. It delineates the different flexibility characteristics of available assets. By matching profiles with one or more other profiles, it reduces the complexity of operations, potentially minimising public grid interventions and the need for balancing power. Thereby enhancing active market participation.

3.9. Benefits of energy cooperations

The benefits that energy cooperations can generate are multifaceted, related to the main purposes outlined above, such as **environmental benefits** [51]; **social**, or **community benefits** (such as, for example, contributing energy or other services to the local community) [54,68,72]; **economic benefits** with a **market focus** aimed at increasing efficiency and profitability to enhance value for members; or **corporation focus** with the goal of expanding and diversification [38]. Additionally, surplus revenue can be distributed as **profit** to stakeholders [50,93]. Typically, consumers benefit through **lower energy bills**, **reduced grid tariffs** [53,99], or **access to complimentary services** such as free car charging for residents [69].

3.10. Challenges

The reviewed literature points out several challenges in the implementation of energy cooperations. Referring to Community Energy Enterprises (CEE), Tricarino [46] discusses that implementation is influenced on the one hand, by **structural assets** (such as national policies, purchase agreements, financial schemes, technologies, spatial assets, and communication campaigns) and, on the other hand, by **intangible assets** (such as organisational and relational capabilities, intellectual competencies, and trust between stakeholders). We have adopted this structure and divided the challenges identified in the literature into these two categories. For a better overview, the results are

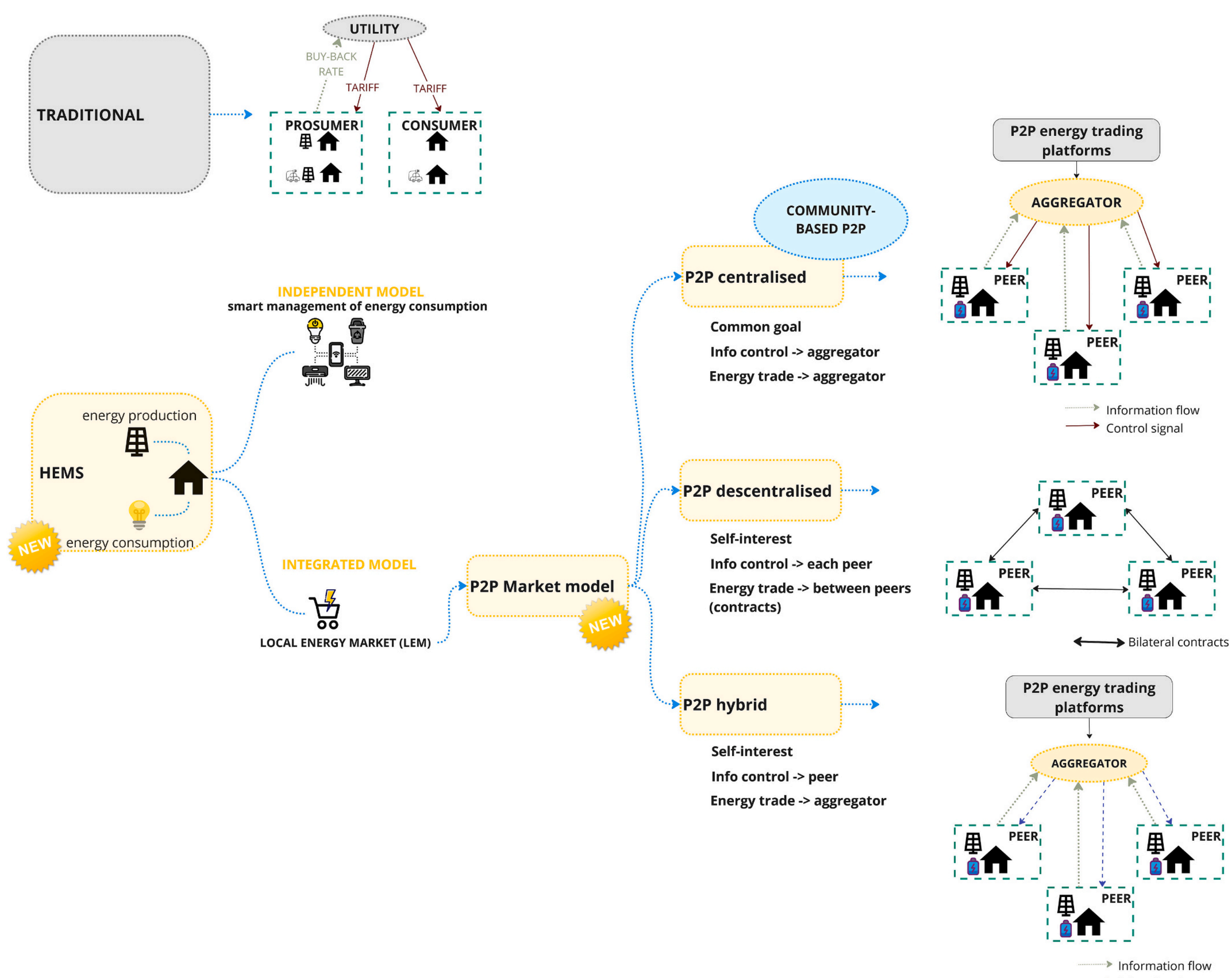

Fig. 8. Scheme energy markets possibilities. Own representation based on [53,70,92,96–98].

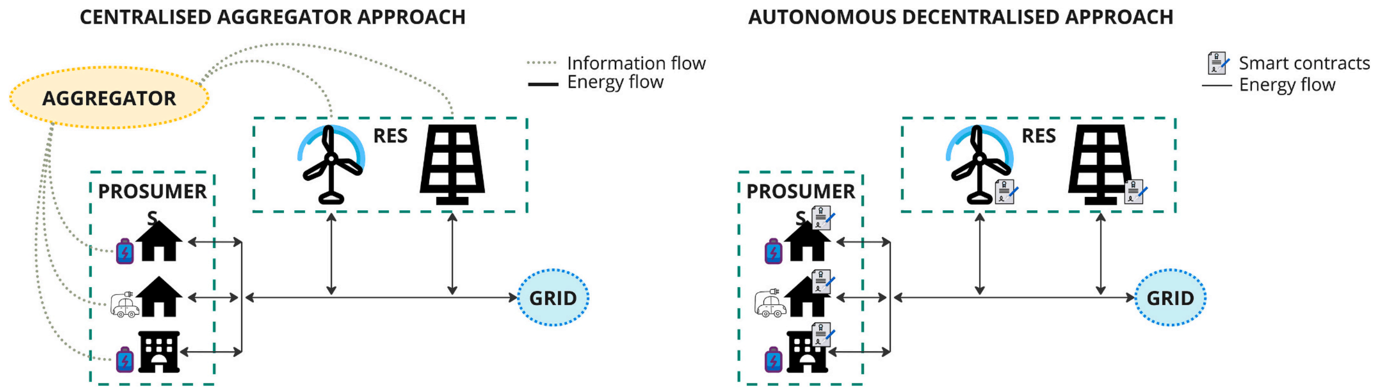

Fig. 9. Scheme of centralised aggregator approach and autonomous decentralised approach [92].

summarised in Table 5.

4. Discussion

While energy cooperations and community-based energy projects are gaining ground across Europe, a multitude of different terms has emerged to describe and define them. Often there are no clear boundaries and distinctions between them. This can lead to confusion or unclear definitions of the different terms and a lack of differentiation in their use - a problem that cannot be solved entirely by this review. Nevertheless, the comprehensive literature review presented in this paper generated valuable insights into the different terminologies and their uses as well as the full spectrum of the possible forms and characteristics of energy cooperations. Although the review focuses on the European level, the following key findings can be applied to any other context relevant to the development and implementation of energy cooperations.

Depending on characteristics of energy cooperations such as the main issues addressed, the scope of implementation, the main purpose, or the main actors involved, a certain tendency of using specific terms can be identified. Terms such as "**initiative**", "**action**", or "**of interest**" typically indicate the motivation of actors to carry out activities with a specific objective; "**collective**" is commonly used for a group of actors working together; "**organisation**" refers to projects that have a structured entity; "**community**" or "**community-based**" are employed when several actors are united in their pursuit of a collective, community-wide goal; "**large**" or "**local**" refers to the size (number of actors involved) and the scope of implementation of the initiative, respectively; "**energy**" is applied when activities pertain to energy-related matters; "**systems**" and "**resources**" focus on the structure of energy management and energy supply; and "**renewable**" is used to emphasise their focus on renewable energy sources.

Of particular interest for this study are those terms that focus on energy initiatives at local level, such as Sustainable Local Energy Initiatives, Local Energy Communities, Local Energy Sharing, Local Energy Systems, and Distributed Energy Systems. They could all be subsumed under the so-called **Local Renewable Energy Organisations (LREOs)**, a concept to keep an eye on as it is considered an innovative concept in the literature that still needs further development.

The most encountered terminology in the literature for describing the organisational principles of energy cooperations is **Energy Community**, followed by **Energy Cooperative**, and **Energy Citizenship**. They are all considered to be civic-focused, driven by societal or environmental purposes, benefitting the community and implementing highly participatory governance structures [48]. Although all these organisational forms pursue civic-focused aims, there are also organisational forms that are predominantly prosumer-focused, or self-focused, although in smaller number. The creation of synergies between different forms of energy cooperations could thereby lead towards the development of **Positive Energy Districts** (PEDs): urban areas or connected clusters of buildings that are energy efficient and flexible, produce net-zero greenhouse gas emissions, and actively manage a surplus of renewable energy on a local or regional basis. They require the integration of different systems and infrastructures, as well as the interaction between buildings, users, regional energy providers, as well as mobility and ICT systems, while ensuring energy supply and promoting a high quality of life in line with social, economic and environmental sustainability [103]. This concept is gaining traction in Europe because of its potential to contribute to the long-term climate strategies set by various countries for 2050 [103,104].

One of the limitations that energy cooperations currently face is the fact that **market adjustment** [40,48,72,100] and **legal frameworks** cannot keep up with the development of energy cooperation forms at local level [11,38,40,48,57,70]. Regarding the latter, it was found that European legislation does not cover all of the above-mentioned organisational concepts, but focuses on four: Renewable Self-consumption, Collective Self-consumption, Renewable Energy Communities, and Citizens Energy Community [6]. The number of nuances found in the literature review, as well as the multiple terms used to define organisational forms of energy cooperation, would need to be thoroughly analysed to provide a clear outline of the structuring principles, hierarchies and characteristics of each. This could facilitate a better political implementation of the necessary regulations at European and national level by broadening the scope of different scenarios, removing regulatory and administrative barriers [54], and supporting the development of national regulatory frameworks to facilitate local energy sharing [48,70].

So-called **hybrid communities** [65,66] – energy cooperations that are integrated by different organisational entities composed of different actors (i.e. Community Energy Enterprises and Energy Cooperatives) – could support the implementation and maintenance of energy cooperations by complementing each other regarding activities, capacities, competences, knowledge, or needs. Hybrid solutions seem to be an interesting and suitable option for further development, as they allow to overcome some of the limitations identified in the literature review, by increasing participants' commitment or mobilising private funding [105]. They also allow for a more professional approach, addressing the need for expertise and professionalism that is often lacking in ECs. This ensures improved development of business models, better market positioning, and consequently, a greater likelihood of sustaining, expanding, and advancing projects over time [65,66].

Motivations for engagement in energy cooperations are manifold [38,76,88], with social, environmental, and economic reasons being emphasised [26,40,50,54,77] – a finding that is also confirmed by other recent studies [106]. Nevertheless, **legal** aspects, **feasibility**, and **ownership** issues are also discussed as potential motivations.

Analysis of the results shows a relation between the main motivations for participation and the potential limitations of such initiatives.

Table 5
Overview of challenges in the implementation of energy cooperations.

Category	Subcategory	Challenges and examples	Refs
Structural Assets	Regulatory Issues	Insufficient (lacking or inadequate) political and policy support for community-based energy projects, both at national and European level, for market development and innovation.	[11,38,45,48,70,90]
		Inadequate rules for management of grid distribution in the operation area (e.g., France, UK: mandatory resale of electricity to national traders).	[38,54]
		Lack of regulatory support for energy sharing systems and market relationships, such as P2P platforms (most EU countries).	[57,70]
		Restrictions on the geographical scope of RECs or on the types of organisations that can participate.	[69]
		Lack of uniformity in the legal approach among European countries (e.g. models of RECs allowed vary from country to country, whether virtual or physical, etc.).	[10]
	Market Issues	Institutionalisation and entrenchment of current markets as a barrier to restructuring them in favour of community business models.	[40,76]
		Low revenues for market parties dependent on transmission tariffs, taxes, and/or surcharges due to regulatory structure and trade-offs for Local Energy Sharing (LES).	[100]
	Spatial Issues	Dependence on biophysical site conditions, uncertainty in social capital benefits.	[38]
	Communication	Additional assistance for wide public communication (especially for technically minded initiators of ECs).	[52]
		Investing in an appropriate information and communication system.	[45]
		Need for embracing innovative solutions and designs for the implementation of energy efficiency improvements, resulting in localised resistance to technological changes.	[69,85,101]
	Technical Factors	High level of uncertainty in energy demand (flexibility) for Distributed Energy Systems (DES) business models.	[72]
		Uncertainty in the performance of the implemented technology, (e.g. discrepancy between projected and actual savings).	[61,85]
		Factors related to maturity of technology for costs and development of ECs (e. g., power grid upgrades, technology access, innovation, communication infrastructure, and system automation).	[10]
		Lack of a simple, secure, and transparent system for RECs generation, monitoring, and control both for operators and users.	[87,88]
Intangible Assets	Management Issues	Need for knowledgeable managers.	[46]
		Bureaucracy and administrative difficulties for RECs to be connected to the grid.	[52,54,69]
		Time-consuming and cost-intensive implementation process of energy cooperations (e.g. especially for Small and Medium Enterprises (SMEs)).	[60]
	Financial Issues	Associated financial challenges: benefit fragility, uncertainty, and context dependency for secure financing.	[11]
		Limited access to capital (lack of investor confidence, high risks, etc.).	[56]
		Community Renewable Energy projects (CREs) focus on survival rather than development.	[24]
		Inclusive involvement within the required financial disbursement that is affordable for citizens with low incomes.	[10]
	Access to Expert Knowledge	Lack of internal expertise.	[85]
		Need for external support (e.g. networking, lobbying, financial and technical support), especially technical support and advice consultation for establishment and development phases.	[52]
	Social Factors	Raising awareness, mitigation and avoidance of local social and energy inequalities and injustices as a factor of age, income,	[10,11,48,65]

(continued on next page)

Table 5 (*continued*)

Category	Subcategory	Challenges and examples	Refs
		educational biases, or 'energy parochialism', sensitivity to environmental issues and climate change or lifestyle.	
		Promoting civic culture towards democracy-based values, with a radical change in collaborative processes.	[88]
	Stakeholder Involvement	Lack of trust and transparency (lack of investor confidence and mistrust in the market, in social organisations, or in innovation professionals).	[46,57,69,85,88]
		Time, driving force capacity, resources, skills, and knowledge levels of volunteers and participants.	[38,48,102]

For example, an environment of **trust** is crucial for high stakeholder engagement [38,39,82,88]. In consequence, a lack of trust can become a significant barrier, affecting not only the relations between stakeholders, but also weakening the confidence in the market, in social organisations, in technology efficiency and performance, and in experts and investors [11,46]. Financial motivations have been highlighted as one of the main reasons for participation, mainly related to **economic incentives**, **fiscal measures**, and **retrofitting** [56,69,79,84,86,87]. These may be related to constraints encountered in ECs and RECs, such as a certain fragility of benefits, uncertainty, difficulty in obtaining funding, the capacity to afford the initial outlay and, therefore, the limited access to capital [56,76]. Looking for ways to enter the market, and solving the problem of energy deficit and surplus that communities may face, are identified as the most pressing economic issues [65]. Within the local energy markets analysed, among the most innovative and relevant solutions are **peer-2-peer trading platforms** [57,107] that create energy networks through **blockchain solutions** [87,92], **cooperative alliances** [66], or **micro smart grids** [88]. Finally, the systems for financing energy initiatives are varied (subsidies, public funding, investments, initial capital contribution plus feed-in-tariff, etc.), but **crowdfunding** is identified as one of the most innovative possibilities [52,56–58].

The range of actors and roles highlighted in the literature is extensive and varies depending on the type of energy cooperation. Nevertheless, the analysis indicates that there is a series of actors that are typically involved and should be considered in the creation and development of any energy cooperation initiative. For the successful development of energy cooperations, it is crucial to identify three dimensions defined by Van der Schoor and Van der Windt [68] from the outset: the **internal network**, **the external network**, and **the material dimension**. It is essential to define the actors involved in the first two dimensions (their roles and level of involvement) and the factors that will influence the third dimension (opportunities and limitations). Some roles are crucial such as the **leader** or **community manager** [68] as is the establishment of **community organisations**; a **founding group** and **creators** of the initiative, as well as **investors** (internal or external) that could be varied, including companies (local businesses specialised in energy community solutions, SMEs' electricity providers, or energy cooperatives) [60], volunteers [52], municipalities, universities, or NGOs [69].

As access to **reliable experts** is also identified as one of the main limitations to the implementation of energy cooperations [10,11,85], the integration of **intermediaries** is pivotal, as they are actors and platforms that positively influence the sustainability of the transition processes. They link stakeholders involved and activities of the energy cooperation, skills needed in it and available resources. They also align stakeholder visions and demands [74], striving to comprehend desires and seek consensus-based solutions [75], fostering collaborations between market-system operators and ensuring adherence to collective agreements [41]. These intermediaries must be **trustworthy**, as a trustful environment is vital for high stakeholder engagement [38,39,82,88] and for promoting awareness for the benefits of low-carbon energy [52,76]. One of the innovative solutions proposed to address this issue is trustee agents, who can act as intermediaries between stakeholders, as well as educators and sources of information and knowledge [52,65,74–76]. For this reason, it is important to involve locally known and socially respected members of the neighbourhoods as well as established neighbourhood associations or community organisations as key actors in the networking process and in communication within the neighbourhood from the outset.

Nevertheless, it is highlighted by some authors that while **systemic** and **niche intermediaries** are essential, they should be complemented by other types, such as **regime-based transition intermediaries** and **user intermediaries** to bridge the gap between technical solutions, business models, and citizens [72]. Considering the material dimension, including **technical** and **bio-physical factors**, is crucial in determining the most appropriate organisational form, as well as its scope, the activities that will be carried out, and the potential limitations it may face.

The importance of the **information** available and the level of **knowledge** of the people involved in motivating them to participate is also emphasised [83]. Raising awareness for the energy transition and its possibilities [10,52,54,82,85,90] as well as careful communication that considers the different levels of knowledge and prior experience, are important factors that help to promote local energy cooperations. For this reason, organising neighbourhood **events** to provide information and establish **contacts** with advisors from different sectors could be important activities to consider. Great importance is attached to providing detailed information and to reflective and sensitive **translation** work between the various stakeholders.

As the participation should be **voluntary** [81] and involve a **broad range of stakeholders** [10,54,82], activities to strengthen social cohesion are crucial to ensure long-term participation. On the one hand, the importance of offering **training programmes**, **one-stop-shops**, or **information campaigns** to improve stakeholders' knowledge, skills, and awareness on energy needs should be highlighted [90]. On the other hand, the creation of **networks of actors** and **energy cooperations** is important to create **collaborations**, **trusting relationships**, and **collective business models** [52,72,87,92] that will contribute to overcome the limitations and uncertainties of technology and promote the **democratisation of energy** [10]. As Causevic et al. emphasise, decentralised sharing of energy resources holds promising potential for addressing future electricity system challenges in the face of uncertainty, as local energy producers are willing to share surplus energy generation [61].

The structure of membership, ownership, and voting system varies with the type of energy cooperation. Nevertheless, in seeking a democratic, not discriminatory [81], and community-based approach, voting systems proportional to shares and exclusive ownership are not adequate [81,93], as they lack inclusivity and concentrate decision-making power among the largest investors. **Cooperative voting**, where each person has one vote, is a widely recognised inclusive system [52]. Yet, there is also interest in exploring **multi-stakeholder** or **collaborative governance models** that build decisions through consensus [10]. It is important to acknowledge, though, that consensus has its drawbacks, such as the potential marginalisation of minority groups with differing views [108]. Therefore, it is crucial to develop systems where all participants can contribute, ensuring consensus is reached with adequate input from all parties [10], without sidelining any group.

The literature review shows that people are found to be more willing to invest in renewable energy technologies if they are installed in **local proximity** to where they live [79] and if they have some form of ownership of the energy generation assets being installed [52]. As Seidl et al. [72] emphasises, **local ownership** of energy solutions, as well as **collective business models** enhance social cohesion within a community and encourage participation in decision-making [50], thus leading towards a democratisation of energy supply and consumption. Furthermore, **feelings of belonging** to a specific place are highlighted in the literature as a factor that positively affects the social acceptance of local energy initiatives [89]. Initiatives to create cooperative energy projects in one neighbourhood can inspire the replication of such initiatives in nearby localities [38]. As innovative socio-technical organisations, cooperative energy projects have the potential to take on a lighthouse function, extending their influence into society well beyond the confines of the project itself.

Finally, we would like to note that the presented study acknowledges the limitations of the classifications, referencing prior research that frames multi-level perspectives under the term ECs [109], with the rich social essence captured by definitions such as collective action initiatives [25]. While the methodology combines systematic, metadata-driven quantitative analysis with narrative-inspired qualitative reviews to balance rigor with adaptability [110] it risks excluding outliers and overlooking geographic [111,112] and historical nuances [113], as well as literature of interest that was published in other databases or in lower impact journals. These constraints, including challenges of overlapping yet distinct scientific indexation systems, emphasise the importance of clear scoping. Nevertheless, this research, focused on capturing a specific period and context, responds to the ongoing need for timely reflections within the evolving energy research agenda [114].

5. Conclusion

The development of energy communities and the promotion of decarbonisation of settlements through the implementation of renewable and local energy production sources has been emphasised in recent years. While European directives mainly focus on Renewable Energy Communities and Citizen Energy Communities, it has been found that the range of terms used in the field is much wider. Often there are no clear boundaries and distinctions between them. This can lead to confusion or unclear definitions of the different terms and a lack of differentiation in their use. The current literature review suggests that in order to provide clarity, it is necessary to delve into the different structuring principles of these various forms of energy cooperation, enabling comparisons across different dimensions such as initiators, participants, organisational or technical solutions, business models, and factors that either facilitate or impede the implementation of energy cooperations. It is also noted that market adjustment and the legal framework cannot keep up with the development of energy cooperation forms at local level. Therefore, it is necessary to open the framework and try to include the different types of structuring principles of energy cooperations, covering the different cases that may arise and eliminating all regulatory and administrative barriers. Therefore, the authors consider it useful to continue to use the term “energy cooperation” as an umbrella term that encompasses the wide variety of cooperative energy initiatives.

The interest of exploring hybrid solutions should also be emphasised. Hybrid solutions can support the implementation and maintenance of energy cooperations by complementing each other regarding activities, capacities, competences, knowledge, or needs. In addition, it is important to implement an inclusive approach to developing and shaping energy cooperations, which aims to democratise the energy transition through broad and extensive stakeholder involvement. The early involvement of technical experts with a deep understanding of state-of-the-art or even innovative technical solutions, as well as regulatory authorities, helps to build trustful networks among different stakeholders. Intermediary actors in particular contribute their expertise to process coordination, project management, and communication skills. They play a crucial role in facilitating translation between technical experts and lay people, and between different stakeholders in general. Thereby, a considered and reflective approach that constantly scrutinises the process, the social dynamics, as well as the targeted technical, legal, and financial solutions is needed in order to mitigate, or at least not exacerbate, the many hurdles and social inequalities integral to the process of decentralised energy transition.

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CRediT authorship contribution statement

Alba Arias: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization, Writing – review & editing. **Oleksandr Husiev:** Writing – review & editing, Writing – original draft, Visualization. **Corinne Schwaller:** Writing – review & editing, Validation, Supervision, Project administration. **Ulrike Sturm:** Writing – review & editing, Validation, Supervision, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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