



Can renewable energy prosumerism cater for sufficiency and inclusion?

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ABSTRACT

By asking how renewable energy sources (RES) prosumerism, integrates sufficiency and inclusivity concerns and/or practices, the study presents the results of a narrative literature review of RES prosumerism research. The review focuses on how these concerns and/or practices emerge across the socio-technical narratives that characterise RES prosumers' research. The study takes stock of a machine-learning topic model and a qualitative thematic coding to identify and discuss key topics, themes, and narrative elements related to sufficiency and inclusivity in RES prosumerism. The results show a crosscutting narrative from early discussions (2005–2018) on energy citizenship, grassroots initiatives, and collective prosumer initiatives, to regulated and institutionalised energy communities (2019–2023). The narrative highlights the relational and systemic dynamics of prosumer projects, embedded in local socioeconomic, sociopolitical, and cultural contexts, and shows that inclusivity and sufficiency have not always been major concerns. However, there are exceptions found in research into “energy commons” and “grassroots innovations”. These findings are discussed in relation to the role of new policy options for sustainable RES prosumerism. The study's conclusions offer therefore policy directions for sustainable energy systems, guided by sufficiency and inclusivity principles.

1. Introduction

Due to the nested challenges of mitigating climate change, preventing loss of biodiversity, and tackling a rising global inequality [1,2], more attention needs to be paid to new policy and governance arrangements that foster sustainable, inclusive, and sufficiency-oriented energy transitions. In this context, global policy objectives such as those embedded in the Paris Agreement and the Sustainable Development Goals are critical landmarks to advance towards addressing socio-ecological challenges. To reach these objectives, policy and innovations must fundamentally challenge the incumbent energy system's structures, cultures, and practices. Renewable energy sources (RES) prosumerism is a transformative innovation with the potential to reduce energy and resource demand while also enabling a more inclusive energy transition [3]. This study hypothesises that the interrelationship of inclusivity and sufficiency concerns and/or practices is central to the development of innovative RES prosumer initiatives that can enable the achievement of the mentioned objectives.

As socio-technical innovations [4], decentralised smart energy

systems can be critical for the fast and widespread adoption of RES, ensuring affordable and clean energy for all [5,6]. The novelty of this work consists, therefore, in bringing to the foreground how RES prosumer innovations contributing to the diffusion of these systems can be interrelated to sufficiency and inclusivity concerns and practices, thus fostering higher sustainability. In so doing, this work aims to open new research directions in the scope of RES prosumerism and raises new questions for understanding sufficiency and inclusivity, which have not yet received enough attention [7].

RES prosumer initiatives are assumed to produce socioeconomic and environmental benefits solely due to targeting renewable energy, yet research lacks a critical approach into whether and how the uptake of renewables can lead to more inclusive and sustainable energy systems. The analysis presented in this study offers then novel insights into policies that can foster RES prosumer initiatives which are more likely to cater to sufficiency and inclusivity. This is done by taking as a starting point a narrative literature review of RES prosumerism research that combines a dynamic machine-learning topic model [8] with qualitative thematic analysis and that represents a novel analytical approach on its own. The review so produced shows how sufficiency and inclusivity

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List of abbreviations:

RES – Renewable Energy Sources

concerns and/or practices are taking shape across the socio-technical narratives that characterise RES prosumers research and hence provides the reference ground to infer new policy strategies in this area.

The driving research question for this work is thus to understand how RES prosumerism integrates inclusion and sufficiency concerns and/or practices. RES prosumer initiatives are socio-technical innovations that involve citizens who participate, either individually or through community-based initiatives, in renewable-based energy systems, including energy production, distribution, storage, sharing, and/or flexible consumption [9,10]. RES prosumers thus offer an example of energy citizenship practices [11], which may comprise different levels of civic participation [12], enacted through diverse consumer and behavioural choices [13], at multiple scales of governance [14,15]. At a political economy level, working towards affordable and clean energy for all requires the widespread participation of citizens in decentralised energy systems, which should be accessible to communities across diverse socioeconomic, sociopolitical, cultural, and socio-technical contexts [9].

Moreover, although research has shown that economic aspects and promoting a sense of citizens' responsibility can engage individuals in RES prosumer communities [16–18], both demand and supply-side relations are equally important in configuring just and inclusive energy systems that avoid ever-escalating levels of resources consumption [19]. RES prosumer policies, to which this study aims to contribute, can therefore, in principle, reconcile goals for more equitable and inclusive energy systems with the urgency for an environmentally sustainable energy transition.

The concept of energy sufficiency [20,21] builds on the idea of achieving actual reductions instead of continued escalations of energy use [22,23]. The importance of sufficiency also relates to ensuring wellbeing for all, which cannot be achieved with efficiency-thinking alone and is increasingly recognised as being incompatible with continuous economic growth [24–26]. Sufficiency is critical for wealthier (e.g., OECD) countries, as overconsumption results in socio-environmental problems [21,27,28]. Current energy policies in these countries are indeed generally informed by a principle of improved efficiency and therefore largely respond to market dynamics rather than exploring transformative pathways enabling zero greenhouse gas emissions and sufficiency [29]. More efficient technologies can also lead to escalating energy demand through the expanding scope of the services they cover [30].

While taking a systemic and relational approach to RES prosumerism, sufficiency-oriented practices are viewed in this study as a possible characteristic of prosumerism. This is grounded on the premise that RES prosumers can acknowledge the need to achieve decent living standards aligned with available natural resources, which are shared equitably [31,32]. In this context, energy sufficiency is here understood as a level of energy consumption that safeguards well-being and social equity while not overshooting environmental limits [20,33]. For instance, rising from poverty (including energy poverty) would imply reaching a level of consumption that is “enough” [34]. In lower-income countries and communities, having enough in terms of energy sufficiency may mean increasing resource use and consumption in an inclusive way. Conversely, considering richer countries and communities, citizens' participation in RES systems should be guided by acknowledging the urgency of reducing the overexploitation of planetary resources [35]. In other words, if sufficiency approaches lead to increased inequality, they cannot be said to properly cater to energy sufficiency.

Inclusivity is defined as the “practice or policy of providing equal

access to opportunities and resources for people who might otherwise be excluded or marginalised (...)” [36]. Thus, inclusivity is the outcome of inclusive concerns and practices. In this study, energy inclusivity is considered to embody the core principles of energy justice, namely the importance of safeguarding the accessibility, availability, and affordability of sustainable RES technologies (including technologies for flexibility, storage and sharing, considering electricity and thermal energy) and energy services for all citizens [37–39]. Social acceptance and participation are equally relevant since an inclusive energy system needs to ensure the possibility of citizens' participation while fostering policies and practices that reflect citizens' concerns [40].

Thus, novel energy policies must pay due attention to the wider effects of new production and consumption patterns, such as RES prosumer initiatives. These initiatives, which in principle imply matching RES production to local consumption in a decentralised configuration, offer new pathways for increasing sufficiency. However, prosumerism may equally widen the gap between those who can participate and those left at the margins of new socio-technical dynamics [11]. Hence, sufficiency and inclusivity are intrinsically interrelated and must be jointly at the centre of an inquiry into the sustainability of RES prosumerism.

The study is, hence, structured as follows: the narrative literature review methodology and data analysis methods are described in Section 2. Section 3 offers a synthesis of the key concepts guiding the inquiry, namely the approach to RES prosumerism as a socio-technical innovation and as a relational and practice-oriented concept. Section 4 provides the results derived from quantitative (machine-learning topic modelling) and qualitative analyses, which are discussed in Section 5. Final policy insights are offered in the conclusion.

2. Material and methods

The methodology of this article is based on a narrative literature review, which is a critical overview of published research on a topic [41]. The review investigates the literature on RES prosumers over the last two decades. It seeks to extract key narrative elements as well as exemplary prosumer projects that characterise how inclusivity and sufficiency concerns and/or practices emerge across the socio-technical narratives that characterise RES prosumers research.

The peer-reviewed articles' sample was retrieved based on regular Google Scholar and Scopus searches. The choice of keywords was informed by an exploratory review regarding renewable energy prosumers, namely: studies offering insights into different organisational typologies (e.g., energy cooperatives, community funds or trusts, public-private partnerships) [42,43]; research into the justice and democratic aspects related to collective prosumer initiatives [38,44], including issues of gender and energy [45]; and studies related to the prosumer model and new technologies and algorithms for the energy sector [46]. Therefore, the following keywords were selected: “energy prosumers”, “prosumerism”, “energy communities”, “community energy”, “energy cooperatives”, “solar communities”, “energy justice”, “energy democracy”, “demand-side management”, “distributed energy systems”, “prosumers AND inclusion”, “prosumers AND sufficiency”, “energy AND inclusion”, “energy AND gender”, “energy AND sufficiency”, “energy sustainability”, and “energy citizenship”.

In total, 1551 articles were retrieved in the first round. Through a second and third round of searches, the list was then refined to articles with contents that referred at least partially to inclusivity and/or sufficiency, in order of relevance. The second round resulted in a sample of 353 articles, which were screened by reading titles and abstracts. Based on additional exclusion criteria, the sample was then further refined to a final set of 241 articles.

Exclusion criteria included articles focused on: (1) technological and engineering aspects of renewables not related to prosumers, or energy communities; (2) ecological citizenship and environmental citizenship not explicitly related to prosumers or energy communities; (3) sustainable consumption more broadly (not specifically with an energy focus);

(4) methods and methodological approaches; (5) global climate change and energy policy, including modelling approaches; (6) social acceptance of renewable energy technologies; and (7) articles addressing the prosumer model more broadly (i.e., not related to energy but to other types of prosumers). Furthermore, grey literature documents were also excluded.

Thus, the final sample of articles included contributions from energy justice literature and community energy research, articles focusing on energy prosumers (individual and collective), including with attention to business models, technological models (i.e., demand-side management and peer-to-peer), and social arrangements (e.g., typologies and categories of prosumers, with a focus on energy cooperatives and community energy initiatives), and research focusing on renewable energy communities, from technological, economic, and social research perspectives. In addition, reviewed articles included studies on energy poverty when related to prosumers or energy communities and articles on sufficiency and on the relevance of decentralised prosumer systems, which explicitly mentioned RES prosumers.

2.1. Data analysis

Data analysis followed a quantitative and qualitative approach. The quantitative analysis took stock of topic modelling, which is a “statistical technique for revealing the underlying semantic structure in a large collection of documents” [47]. This analytical technique was applied to the articles’ abstracts, while the following qualitative analysis entailed reading the full-length articles to explore key themes based on the general topics derived from the topic model. Diverse Python libraries were used for producing general statistics as well as the topic model. First, Litstudy is a Python code package for literature reviews [48] which was used for producing basic statistics. Second, the pyLDavis library [8], was used to produce the topic model.

PyLDavis is a Python library for interactive Latent Dirichlet Allocation, which is a topic model method. The machine-learning Latent Dirichlet Allocation algorithm enables extracting keywords and creating a corpus of words (i.e., tokens) based on which the key topics covered by the articles can be extracted. The pyLDavis library works together with other Python libraries, namely the Gensim Library for topic modelling and natural language processing [49], as well as Pandas, Numpy, Matplotlib (used for data visualisations) and Scikit-learn [50]. Python libraries were chosen instead of other tools because they are open-source and freely available for use and re-use.

The PyLDavis package [8] offers a step-by-step framework for producing the machine-learning topic model leading to the dynamic visualization of the results. First, after loading a spreadsheet file with the text sample (i.e., the article abstracts), a set of functions is used to remove “stop words” from the text. “Stop words” carry little information, they include commonly used words in English such as “the”, “a” or “but”, so it is important to clean the data by removing them. Second, a “dictionary” and a “corpus” are created by assigning to the remaining tokens (i.e., words), an identification number and a frequency (number of times the word appears). Third, to prepare the corpus of text and prevent outliers within the model, the tokens that appeared in less than five documents are filtered out, as are those that appeared in more than 50% of the corpus.

Forth, as the data for the unsupervised machine learning model is ready, the model is trained using the LdaMulticore Python library, which is also included in the pyLDavis package [8]. By counting the words (frequency) and identifying words that appear together in the same document (i.e. abstract), the model uncovers patterns within the data, and groups words together (e.g. topics). As an intermediate step, it is important to determine the optimum number of topics that capture the variety of the data. For this purpose an algorithm from the Gensim library [49] is used (i.e., the coherence score), which provides a score from complete incoherence (0) to complete coherence (1), producing a sequence of values with a recommendation for the optimum number of

topics. Finally, the model is built with specifications on the number of topics to be retrieved. To visualize the final topics, pyLDavis includes an in-built dynamic data visualization tool, which represents most of the information of the resulting topic model (this code is used to produce Fig. 6 in Section 4.1).

Guided by the results of the topic model of the articles’ abstracts, the following qualitative analysis took stock of the thematic coding of the contents of the articles reviewed. Thematic coding is an important analytical approach for analysing narrative data [51,52], as the narrative elements can be extracted through the identification of key themes. The identification of the qualitative themes was based on a set of criteria, namely: recurrence (repeated concepts or ideas); repetition (an idea conveyed using the same words); and forcefulness (emphasis applied to a concept) [53]. The narrative analysis equally took stock of intra-themes (those that relate to a specific topic covered by the article reviewed) and inter-themes (comparing topics) [53]. Based on the findings from the narrative analysis, an overall narrative depicting research into RES prosumerism has been constructed while highlighting how sufficiency and inclusivity were integrated. The narrative review methodology is illustrated by Fig. 1.

2.2. Limitations of the data analysis

There are two main limitations to this study. First, as a review study, the work does not directly capture prosumers’ perceptions about how their practices are contributing, motivated, or framed by concerns with sufficiency and inclusivity. Although this limitation is methodological, there has been an effort to review articles, whenever possible, that provide specific evidence of citizens’ experiences. A second limitation is geographical, as most articles (i.e., 218 out of 241) included in the sample have a Northern and Western European focus, although the search criteria were not restricted to European research. Also, the articles with studies from Southern Hemisphere countries focus mainly on studies of grassroots innovations involving local thermal energy projects (e.g., solar ovens) [54], with only two articles focusing on electricity production [55,56]. This geographical limitation reveals the lack of studies about prosumers in developing countries and raises the question of whether RES prosumerism is in practice mainly a Northern and Western model.

3. Theory and concepts: prosumerism, sufficiency and inclusivity

The prosumer term was first introduced by Alvin Toffler in the “Third Wave” (a term he used to refer to the transition of developed countries from an industrial to an information-age society). Toffler argued that the line between producer and consumer would be progressively blurred across all economic sectors because of a return to production for personal use [57]. Prosumerism is, thus, in its original definition, related to a specific socio-technical configuration characteristic of developed and industrialized societies at the onset of digitalization.

In this context, the proposal for a literature review on the intersection of RES prosumerism, sufficiency, and inclusivity departs from an approach to RES prosumerism as a socio-technical innovation [58,59] and as a relational and practice-oriented concept [60]. This systemic and relational approach calls for a critical discussion of the prosumer model in inclusive and sufficiency-oriented distributed and smart energy systems across the world [61].

In sustainability transitions research [62,63], the combination of a systemic and relational approach has framed a critical perspective to social innovation studies [58], including the study of social innovations in community energy [42], but also in research into the social acceptance of renewable energy technologies [40] and into the participation of citizens in the energy transition [64]. Crosscutting these systemic and relational approaches is the understanding of collective agency as being socially constructed, connected to wider sociopolitical, socioeconomic,

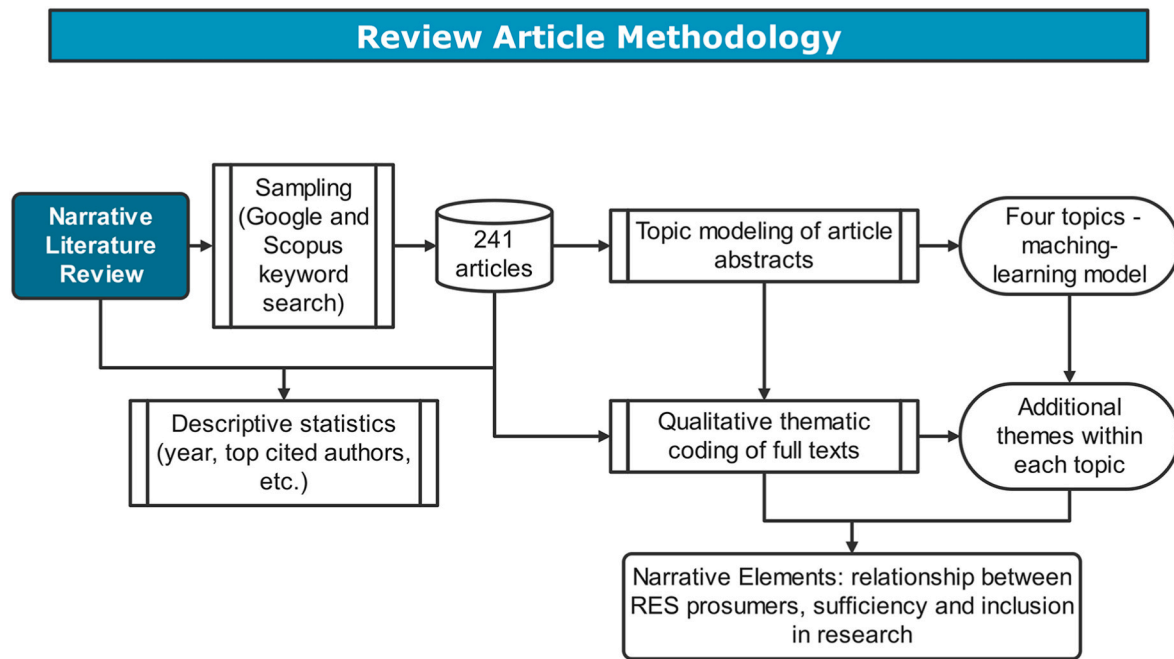


Fig. 1. Flowchart of the methodological steps.

cultural, environmental, institutional, and technological settings, and framed by diverse social practices embedded in these systems [65,66].

Thus, RES prosumerism is proposed in this work as being embedded in other consumer practices, interrelated to cultural and socio-political contexts, which may either discourage or encourage citizens and community participation in new prosumer projects. Such projects may offer benefits for both participating citizens and for the sustainability of energy systems. Accordingly, social practices, cultures, and institutions frame citizens' capacity to assume the role of prosumers in the first place [43], and thus to be included, or excluded, from distributed and smart energy systems, while also conditioning their interest in and motivation to focus on sufficiency goals [28].

Furthermore, RES prosumers offer the potential to re-combine socio-technical energy production and consumption dynamics, which can challenge general distinctions and dichotomies traditionally established in the context of technological innovations between, e.g., experts and laypersons, governors and governed [67]. Thus, RES prosumerism brings to the foreground new relationships between energy and social practices, norms, and cultural contexts [3].

If RES prosumers are critical actors in a sustainable energy transition, it then becomes relevant to understand whether and in what ways RES prosumerism can contribute to resolving persistent problems of inequality and injustice within energy systems [38] and the environment [23], incorporating a focus on inclusivity. RES prosumers come in diverse types [43], including individuals producing and self-consuming renewable energy produced by solar panels on their rooftops and groups collectively owning the resources (e.g., a wind or a solar farm) and the technological equipment (e.g., smart meters) they employ.

While representing new ways of thinking, doing, and organising around energy, RES prosumer collectives are also described as social innovations [42], which can take various organisational forms [42] such as public-private partnerships and municipal projects with the participation of citizens [30]. One of the most common organisational forms is the renewable energy cooperative (i.e., so-called "REScoops"), in which citizens are shareholders and collectively invest in and operate RES projects [63]. REScoops offer hopes for a higher degree of energy democracy (i.e., citizens gain democratic control over energy policy implementation) [67], thus being more inclusive, as citizens can participate in energy decisions [67]. However, there are several

limitations to the inclusivity of REScoops.

First, while electric cooperatives have been historically critical for the electrification of the rural world across the globe, with several examples from Europe, the United States, and Africa [68–70], REScoops have been important for the expansion of collective RES prosumers in Europe and North America but are less present in the Global South [71–73]. Second, aside from its geographical limits, REScoops require that prospective members have some spare capital to invest (e.g., membership entry costs may be anything between 60 and 250 euros or more). Only after joining the cooperative as shareholders can citizens become full members with decision-making rights at the general assembly. As such, although cooperatives offer a wide range of opportunities for participation and therefore embody principles of energy democracy [67], they may exclude large segments of impoverished populations, even in more developed countries.

Community-driven RES prosumer initiatives may also be embedded in decolonization goals [74,75]. Research into the main motivations for off-grid indigenous communities in Canada to participate in renewable energy initiatives concluded that self-sufficiency is central for these communities. Although self-sufficiency is different from sufficiency, self-sufficiency will require attention to sufficiency as the installed capacity will need to match as much as possible local consumption needs to enable off-grid systems [76]. Studies of the experience of First Nations in Canada equally found that to be self-sufficient, implied communities enjoyed both material self-sufficiency and political self-determination, leading to the interpretation of the interest of indigenous communities in renewables as a process of decolonization [75].

The possibility to participate in new RES prosumer projects should equally benefit people in the countries most affected by climate change, who are still lacking access to clean energy [77,78]. These communities should profit from the opportunity to actively participate in new energy systems, rather than being subject to economic and socially unjust processes that may result from the energy transition [79].

In the context of sustainable smart energy systems, RES prosumers are also analysed as "radical innovations" [80], implementing new models of consumption based on flexibility technology. In these models, consumers may voluntarily adjust their consumption routines to dynamic electricity prices. Alternatively, if supported by new aggregator services (i.e., services that aggregate electricity supply from multiple

distributed consumers to then sell the aggregated energy in energy markets) [81], prosumers may also be rewarded by their flexibility by benefiting from discounted prices. These scenarios are promising for sufficiency purposes, since by avoiding peak moments of consumption through demand-response (either voluntary or incentivized by aggregator services), the energy balances within the system are likely to be more adapted and optimised to local consumption needs [82]. “Peer-to-Peer” services, involving distributed generation technologies, smart meters and blockchain technologies (i.e., a technology that enables a real-time ledger of transactions), also cater to the entry of new actors with new relevant roles across the market, government, third sector, and community spheres [46,83].

However, while distributed smart technologies are promising for a

more sustainable energy system [84], it is relevant to ask how inclusive and sufficiency-oriented they are. Will all countries and societal groups be able to equally benefit from these technologies? Or are they a niche innovation, while the majority of regions and countries will instead be powered by large-scale renewable energy installations, often implemented with very little or no participation of local communities [59, 85]?

These innovative forms of digital energy management raise similarly other questions of equity, namely, whether all citizens are equally able to change their consumption routines, i.e., is flexibility inclusive? If smart energy systems can indeed be radically different from previous centralised and demand-driven energy systems, then it is relevant to understand if unequal opportunities to benefit from distributed energy

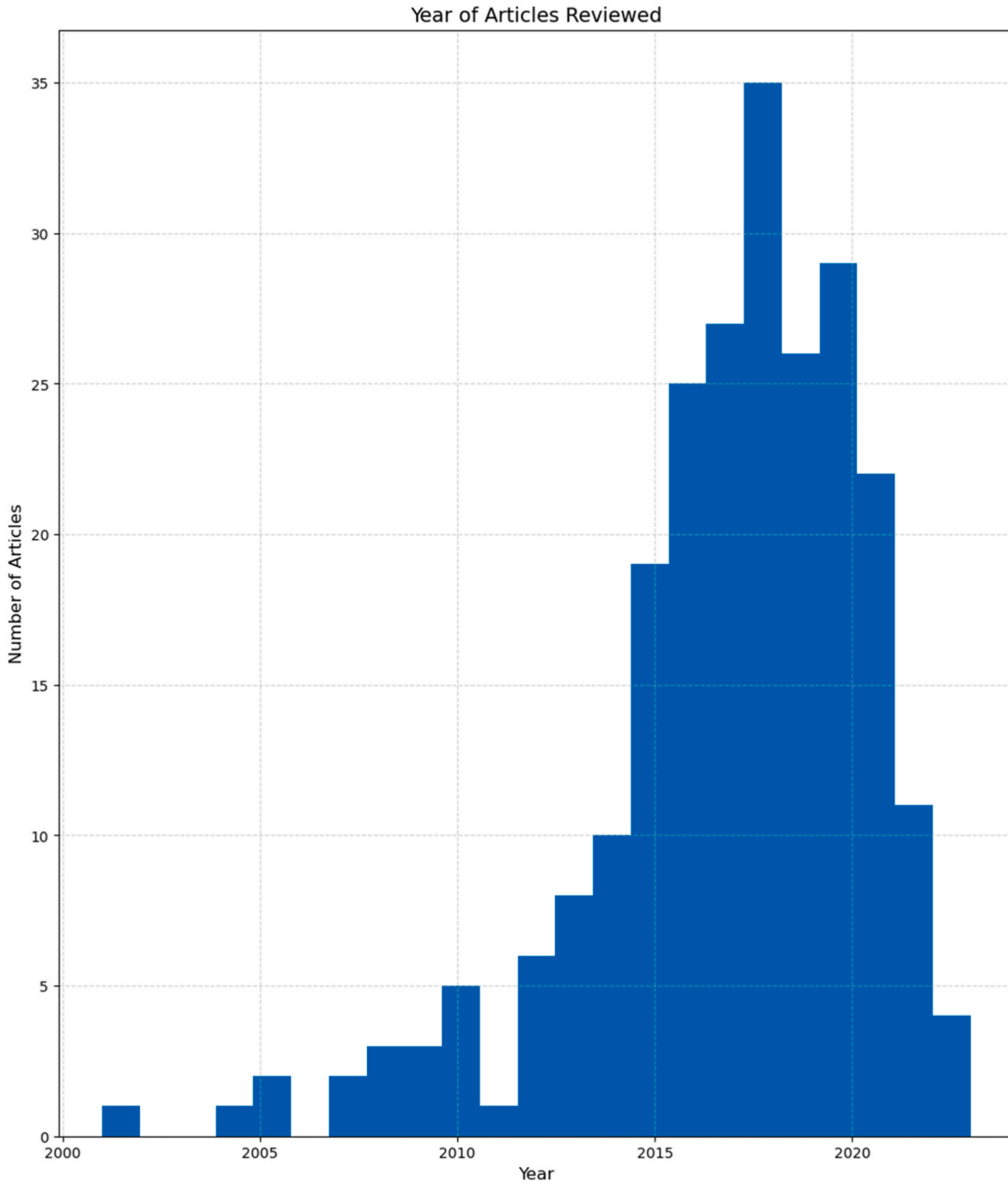


Fig. 2. Number of articles reviewed per year of publication.

supply can also be met. There are some indications that flexibility is likely not inclusive, as it is conditioned by wider everyday life practices, including working routines [39]. Even in richer Northern European countries, electric mobility, or “vehicle to grid” transport, may be confined to rich and white-male ownership, leaving more vulnerable and rural communities, as well as women’s participation at the margins [79]. Such a lack of “fairness” in new smart systems will equally condition possibilities for sufficiency, as the optimisation of distributed systems may be compromised by dynamics that shift from peak surplus energy production to overconsumption. Thus, smart systems are not inherently leading to sufficiency nor to inclusion.

4. Results

In what follows, the results of the summary statistics, the topic model, and the qualitative thematic analysis of the 241 reviewed articles are provided to highlight interrelationships among RES prosumers, sufficiency, and inclusion. Next, the narrative findings of the review are described, including the presentation of some exemplary cases of RES

prosumer initiatives, illustrating the relational and systemic dimensions of RES prosumerism.

4.1. Summary statistics and topic model

Most articles reviewed were published between 2007 and 2023, as shown in Fig. 2, although the earliest article is from 2001.

The median value for citations is 64, with a minimum number of 0 citations (namely for articles published in 2023 that had not yet been cited when analysis was conducted) and a maximum of 1221 citations (Andoni and colleagues article on blockchain) [86]. Other highly cited articles include Seyfang’s (2012) article on community-based energy initiatives as “grassroots innovations” (866 citations) [87], and Parag’s (2016) article on “electricity market design for the prosumer era” (741 citations) [88]. The top 10 authors, in terms of the most cited articles published on topics related to RES prosumerism, sufficiency, and/or inclusion, are illustrated in Fig. 3. Of significance, except for Merlinda Andoni and Gill Seyfang, who are respectively the first and third most cited authors, most of the ten top authors appear to be men, indicating

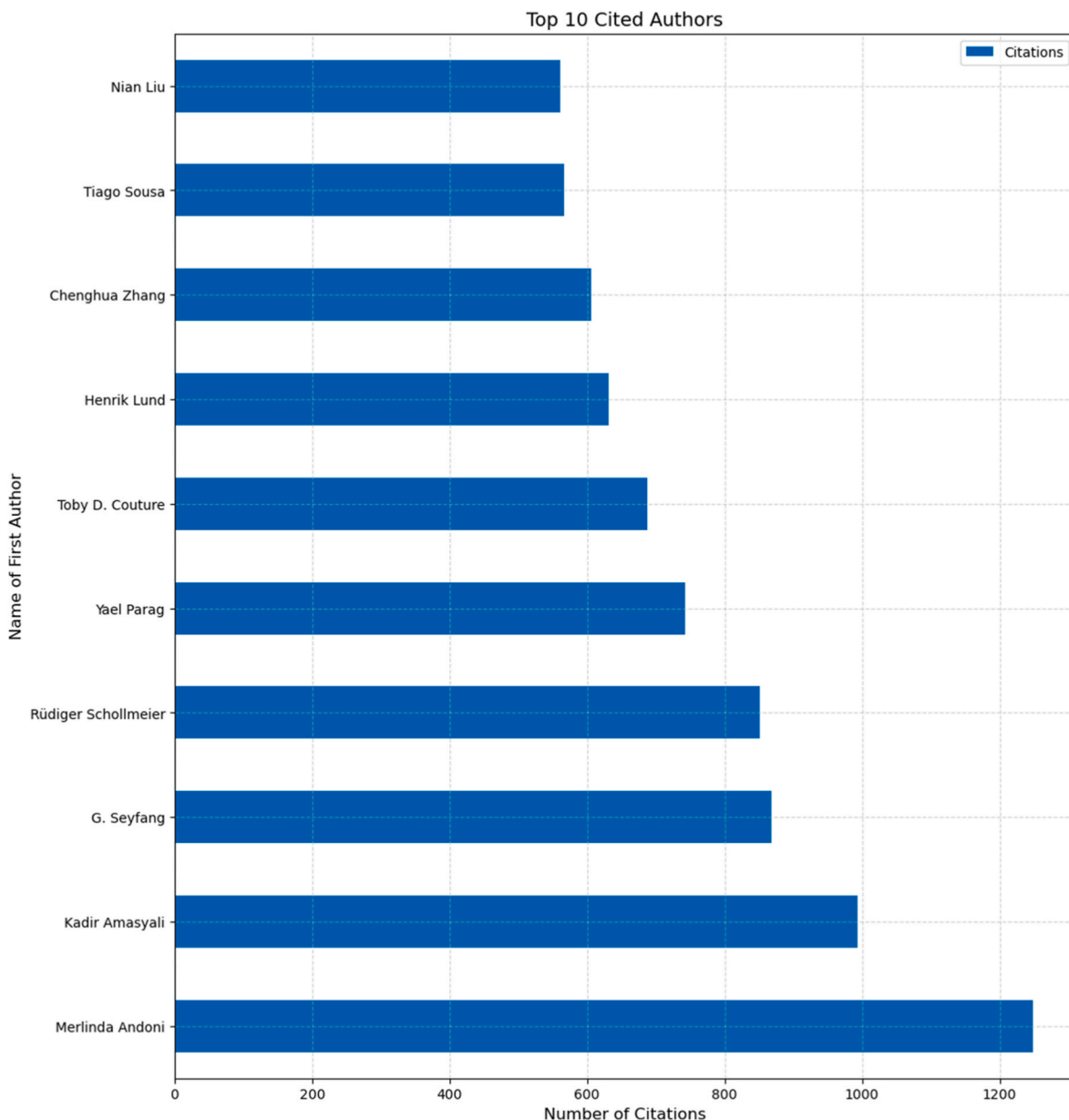


Fig. 3. Top 10 first authors in terms of the number of citations in the articles reviewed.

this literature has a strong male author lead, with the majority being from European countries.

Concerning the publishers, the main journals were Energy Research and Social Sciences (36) and Energy Policy (33), followed by Renewable Sustainable Energy Reviews (17) Energies (12), Local Environment (8), Applied Energy (7), Sustainability, Journal of Cleaner Production, European Journal of Social Theory, and Energy, Sustainability and Society all with 6 articles each. Fig. 4 shows the top 20 journals as regards the number of articles published (some journal names were abbreviated to improve the readability of the figure). All other journals published only two or less articles of those included in the sample.

The automated word analysis across the articles' titles revealed the following key words (i.e., most repeated words based on percentage of the documents reviewed): "community" (27%), "renewable" (20%), "transition" (14%), "systems" (10%), "prosumers" (10%), "sustainable" (9%), and "justice" (8%). Fig. 5 presents a word cloud of the top key words across the titles of the articles reviewed. Furthermore, when

considering the year of publication, the word "prosumer" was increasingly used in the titles of publications after 2016 (following the Paris Agreement and EU proposals for the Clean Energy Package).

In addition, the machine-learning topic model applied to the articles' abstracts returned four topics. These topics provide a broad categorisation of the articles since they result from the analysis of the abstracts only. Table 2 presents the main tokens (i.e., words that appear most often together in the abstracts), of the topics retrieved. Based on the most frequent tokens for each topic, the authors attributed a title to the topic. These qualitative themes discerned from the abstract titles are broken down into other themes in the following narrative review presented in Section 4.2.

Comparing the four topics, topics 1 (n = 152) and 2 (n = 50) together comprise most of the abstracts. Topic 1 is framed by a focus on the potential of community energy for sustainable consumption. This topic includes articles on grassroots communities as well as articles about the peer-to-peer model. Topic 2 has a thematic focus on renewable energy

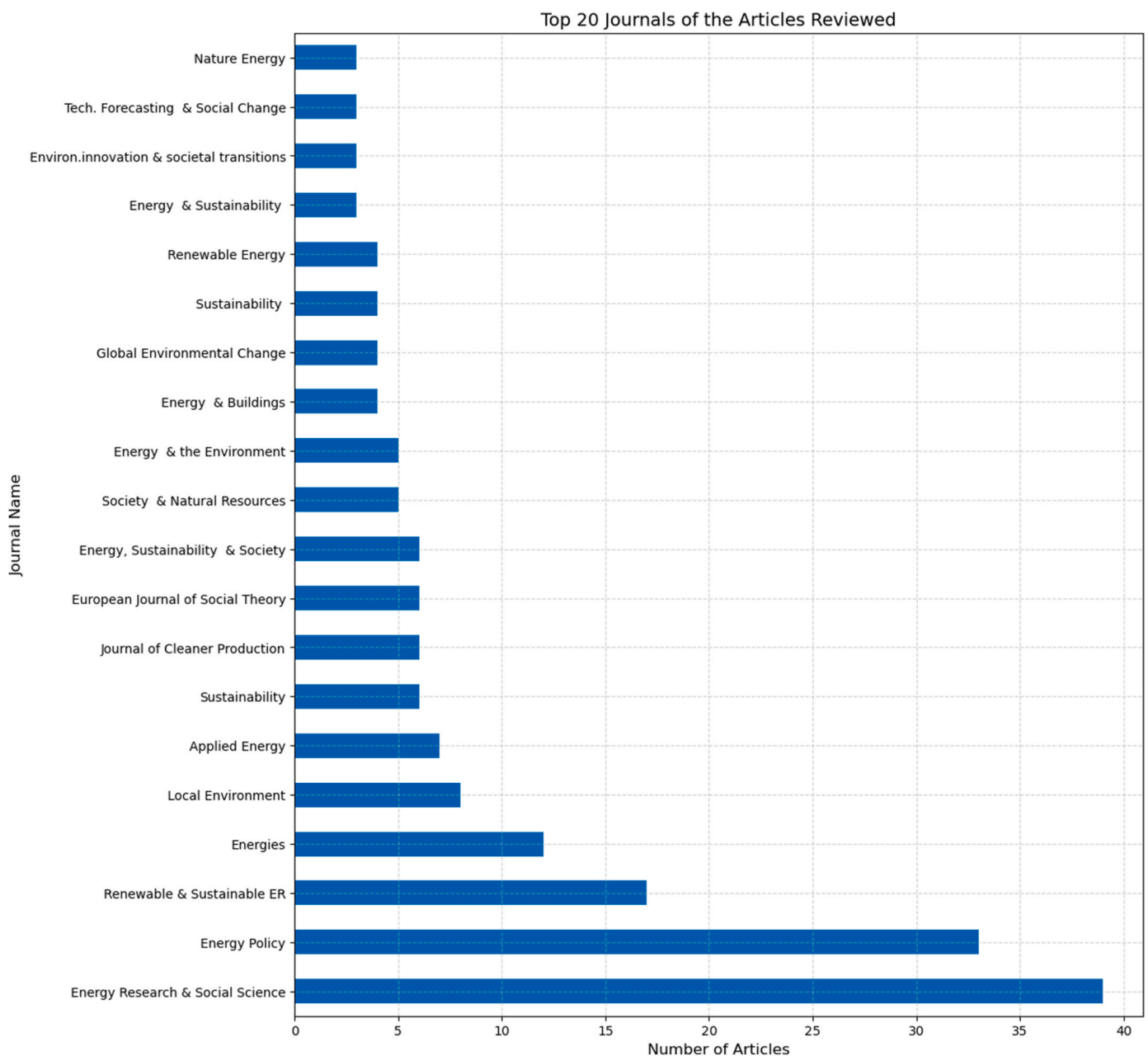


Fig. 4. Main journals where the articles reviewed were published.

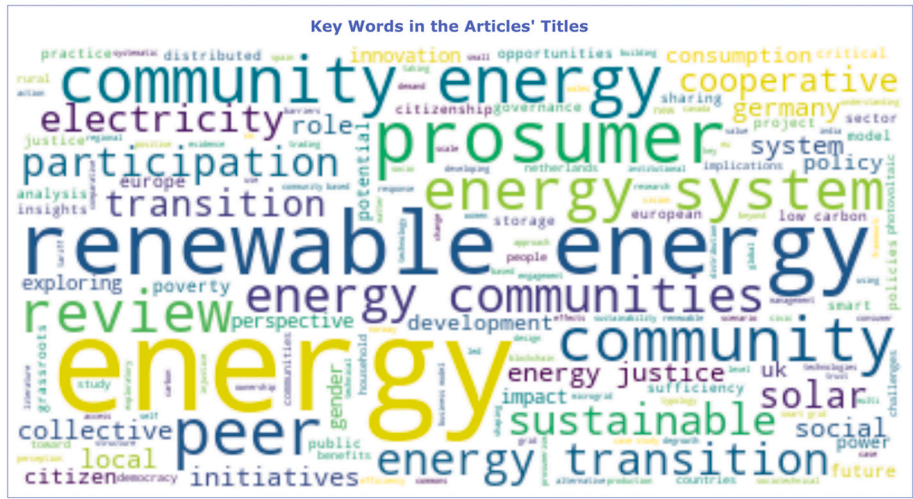


Fig. 5. Word cloud of the most common key words in the articles' titles.

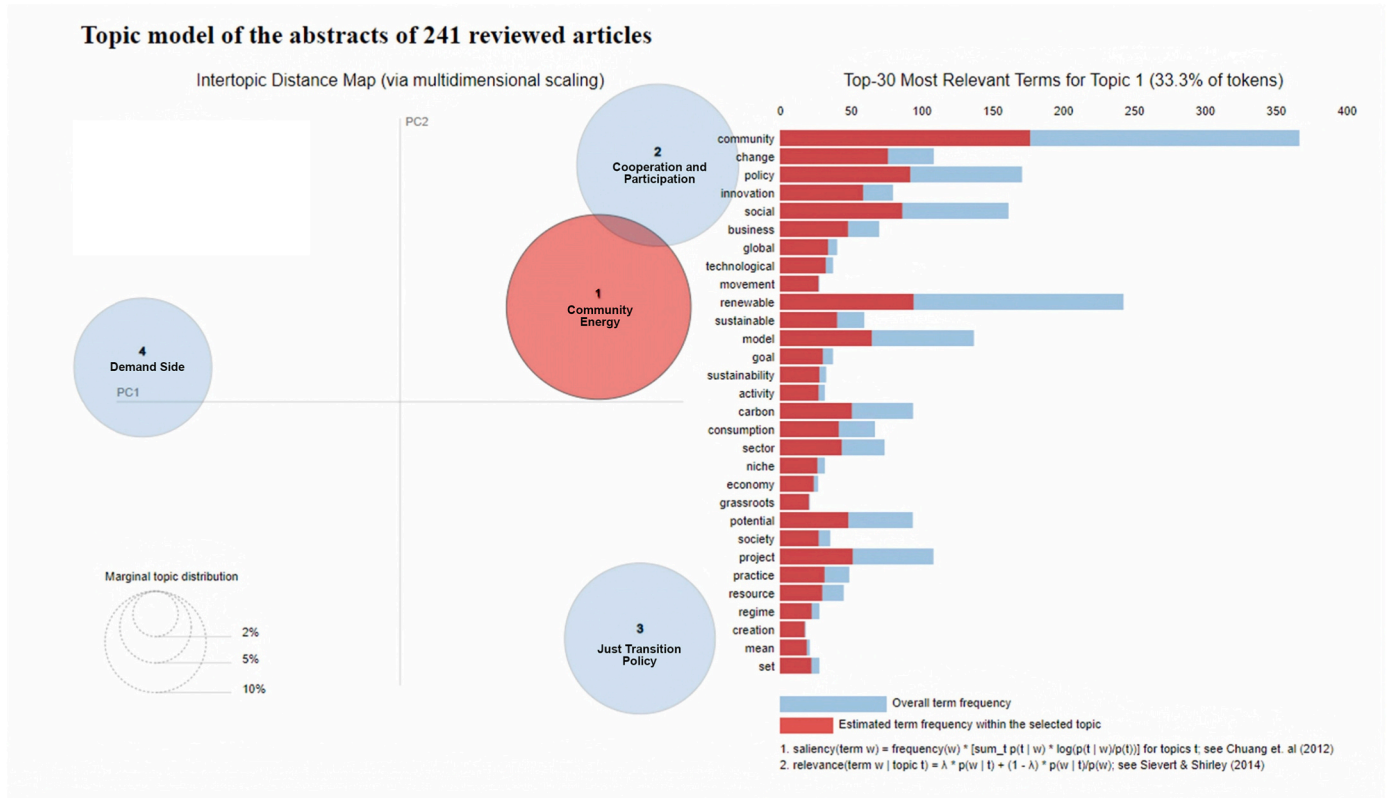


Fig. 6. Illustration of the interactive visualization (topic 1 is selected) showing the distribution of topics retrieved from the articles reviewed and the respective token frequency. The complete interactive visualization can be viewed here: <https://inclusivefuture.eu/grafico.html>.

cooperatives as well as citizen participation in decentralised energy systems. Topic 3 ($n = 25$) is centred on justice aspects in relation to renewable energy technologies and energy and climate policy, but also on the role of energy cooperatives in this context. Lastly, topic 4 ($n = 14$) has a technological focus, including smart systems, microgrids, and demand-side management. Although none of the topics explicitly includes the words “inclusion” and/or “sufficiency” as key tokens, they nevertheless include other words (e.g., “justice”, “gender”, “poverty”, “self-”) that may be interrelated to sufficiency and inclusivity concerns and/or practices in the full-length articles.

The distribution of topics is represented in Fig. 6, which is a snapshot

of a dynamic visualization (developed using the pyLDavis Python package [8]), of each topic and the respective frequency of each token (or word). The graph on the left represents the “intertopic distance,” indicating how topics relate to each other and how they intersect. For instance, topics 1 and 2 intersect (they have in common the token “community” with the highest frequency), while topic 4 is almost on the opposite spectrum in relation to the other topics. On the right side of the visualization, the bars indicate the relative frequency distribution of the key tokens that define the topic in relation to the overall frequency of each token.

4.2. Renewable energy sources prosumers narrative

The four topics extracted from the 241 abstracts supported the identification of qualitative themes based on the review of full-length articles (see Table 1). Thus, within the “community energy” topic, themes qualitatively identified include “grassroots innovations”, “prosumer collectives”, “energy communities”, “energy autonomy (indigenous communities)”, and “autarky”. The “cooperation and participation” topic includes the “cooperatives”, “business models”, and “active energy citizens” themes. The “just transition policy” topic includes the “energy justice”, “gender-energy”, and “new regulatory frameworks” themes. Lastly, within the “demand-side” topic, themes include “demand-side-management” and “energy commons”. This qualitative thematic coding guided a narrative analysis of how prosumerism, sufficiency, and inclusivity are interrelated. Table 2 summarises the themes and the different narrative elements identified based on the thematic analysis. This table is at the centre of the discussion in Section 5.

RES prosumerism has been approached in several ways, such as simply “prosumers” (referring to individuals), but also as “community energy initiatives”, “renewable energy cooperatives” and more recently as “energy communities”. The different designations reflect the overall narrative about how RES prosumerism has been approached by academia. At the governance and institutional levels, definitions have been introduced in European Union legislation through the REDII and the Internal (Electricity) Market Directives [111]. In the United States, specific definitions of energy cooperatives are proposed by the National Cooperative Business Association [116]. These definitions have been likewise integrated into research.

A first moment in the RES Prosumers narrative (2005–2013) is characterised by a substantial body of highly cited research, as represented, e.g., by the work of Devine-Wright and Walker [96,117]. This work is focused on citizens “motivations” to engage in community energy projects. There is a concern with the ambitions driving individual citizens and with the proposed concept of “energy citizenship”, which is only widely taken up by literature more than a decade later [11,44]. Nevertheless, Devine-Wright’s proposal for energy citizenship [104] explains the possible drivers for citizens’ participation in community action and in energy cooperatives. These drivers include an ambition to contribute to the common good by doing their bit to address climate

change and foster the mainstreaming of renewable energies. Both sufficiency and inclusivity (in terms of considering who may be excluded from participation) are not fundamental concerns at this moment.

From a socio-technical perspective, there is a critical turning point (2012–2014) with the proposal for approaching community energy initiatives as “grassroots innovations” in the highly cited articles by Seyfang and colleagues [89,118]. The concept of grassroots innovation implies that citizens are developing innovative solutions at the local level to address critical problems when institutional and government responses fail. In this sense, inclusion is inherent to grassroots innovations, such as local solar communities in India, led by women [110]. Grassroots solutions are fundamentally context-specific, as they aim to address local problems, such as lack of access to clean energy sources. In this sense, although sufficiency is not an explicit goal of grassroots innovations, these innovations may be enacting sufficiency-based solutions through the sustainable use of local energy sources [119].

The following literature (2014–2020), includes several contributions from the sustainability transitions research field focused on community energy as a socio-technical innovation [120–123]. In parallel, new technology and information research have an interest in the potential of peer-to-peer and blockchain technologies. These enable real-time tracking of consumers’ energy use and energy data exchanges through the widespread adoption of “smart-meters” and a growing number of digital applications, mainly in the context of experimental and pilot cases [46,124]. From this point onward, RES prosumers are, for the majority, approached as a “socio-technical” innovation.

Studies of renewable energy cooperatives [63,72] also touch on the topic of inclusivity, as cooperatives are thought to cater to a fairer model of citizens’ participation in energy decisions. Research into “energy democracy” often refers to energy cooperatives as examples of a democratic decision-making process [125]. Sufficiency, however, is less emphasised, although energy cooperatives are perceived as being more sustainable, and cooperative members may be concerned with the need to reduce excessive use of resources for energy production [102].

A second turning point comes with new EU legislation in 2019, which provides a regulatory framework for collective RES production and self-consumption in European Member States [111]. Gradually moving away from RES prosumer collectives as grassroots innovations, literature largely adopts the EU legal concepts of “renewable energy communities” and “citizen energy communities” [126–129] to further understand how to foster the development and widespread implementation of these communities through new business [10,112], as well as technological models [83,84,130].

There is likewise the uptake of “Positive Energy Districts”, (PEDs) proposed in the context of the Energy Union’s SET-PLAN. These are districts with an annual net zero energy import and net zero CO₂ emissions, and their implementation implies a coordinated effort (between energy generation, end-users, and storage activities) of multiple stakeholders to implement solutions leading to this outcome [131]. PEDs can interlink diverse individual installations but may also be treated as a particular type of energy community that benefits from a circular, and stakeholder-centric approach with potential local economic and environmental benefits, where sufficiency is also a concern [35]. However, PEDs do not explicitly address inclusivity, such as considering issues regarding who is left out [132]. In this context, demand-side management studies equally take stock of the notion of prosumers, with self-sufficiency being addressed mainly in the context of buildings [76].

A parallel and less-cited literature explores community energy as a “commons”, drawing on the seminal work of Ostrom [133] and a socio-ecological systems framework. Byrne’s article [134] is specifically concerned with how “community-scale renewables” can help reduce energy use while catering to local energy needs. Thus, it has an explicit focus on sufficiency while advocating that the energy system needs to move from a “commodity” to a “commons”. Taking stock of this

Table 1

Topics retrieved from the analysis of the abstracts and key tokens.

Abstract topics (number and title)	Number of articles per topic	Key tokens	Example of articles in topic
1 Community Energy	152	Community Renewable Policy Social Change Model	[89,90]
2 Cooperation and Participation	50	Community Renewable Local Transition Cooperative Citizen	[7,88]
3 Just Transition Policy	24	Justice Technology Transition Prosumer Research Process	[91,92]
4 Demand-Side	14	Electricity Prosumer Peer Power Grid Cost	[93,94]

Table 2
Summary of narrative elements taken from a review of 241 research articles and their relevance for sufficiency and inclusivity.

Article references	Themes	Are sufficiency and Inclusion relevant?	Narrative elements
[87,89]	grassroots innovations	Sufficiency is not a central concern, although environmental concerns are important, including excess consumption of material goods. Inclusion is important.	Studies focus on how grassroots innovations address local community needs to which governments fail to respond. Inclusivity is a key principle for their development.
[17,95]	prosumer collectives	Sufficiency and inclusion are marginally considered.	Studies on the organisational forms of prosumer collectives attempt to map the diversity of governance arrangements.
[96,97]	energy communities	As self-consumption collectives, communities should be able to optimise their consumption in practice and cater to sufficiency-based models. Also, energy communities should be able to benefit lower-income households.	Sufficiency and inclusivity in energy communities are argued to depend on the organisational and ownership models, as well as the technological and business models that are set up.
[98,99]	energy autonomy (indigenous communities)	Sufficiency is addressed as “self-sufficiency” and the ambition to be “autonomous”. There is a focus on inclusivity.	Studies of RES prosumerism in indigenous communities conclude key drivers for prosumer projects are energy autonomy and self-sufficiency.
[100,101]	autarky	Sufficiency is an important focus. Inclusivity is marginal.	Autarky models imply households become independent from energy utilities and markets. Studies focus on the perceived benefits of this model and how to measure (self-)sufficiency.
[63,102]	cooperatives	Sufficiency is not always a concern, but cooperatives aim to meet their members’ energy needs through cooperative investments. Inclusivity is a concern, with a focus on energy democracy.	The focus is on who owns and benefits from new RES systems and the principle that citizens should be key shareholders of new renewable energy infrastructures and have an active role in decision-making.
[10,103]	business models	Sufficiency and inclusivity are only marginally considered.	New business models are proposed for prosumers for exchanging surplus energy and maximising energy efficiency.
[11,44,104,105]	active energy citizens	Sufficiency is not specifically addressed. Inclusivity is a concern.	RES prosumers are exerting a high level of energy citizenship. Research emphasises energy citizenship as a form of citizenship in democratic governance that needs to be inclusive.
[37,106–108]	energy justice	Sufficiency is not directly addressed. Inclusivity is strongly considered. Studies, with a focus on procedural, distributive, and recognition justice.	Studies explore how and to what degree different dimensions of (in) justice are reproduced in new decentralised RES prosumer systems.
[109,110]	gender-energy nexus	Sufficiency is addressed as a goal to reach a minimum level of wellbeing and access to clean energy sources in developing countries. Inclusivity is a concern.	Studies focus on women’s participation in new decentralised energy systems, including energy communities, with few examples from the Global South.
[111,112]	new regulatory frameworks	Sufficiency is considered in collective self-consumption (i.e., installed capacity should match consumption). There is a focus on inclusivity, as energy communities should be accessible to all, and help tackle energy poverty.	The European Union launches in 2019 a recast of its energy directives, which include legal definitions of collective self-consumption, and of energy community models.
[93,113]	demand-side-management	Sufficiency is an important focus. Inclusivity is only marginally considered.	Demand-side management is a focus of technological innovation in energy engineering, first with studies on individual prosumers, and later with collective arrangements.
[114,115]	energy commons	Both sufficiency and inclusivity are central aspects.	New grassroots discussions, with energy conceptualised as a common good.

approach, articles by Becker and Kunze [97,135] propose energy collectives as a “public commons” and advance with insights into the role of municipalities (i.e., discussing the role of “re-municipalization”), in fostering more inclusive and politically-motivated RES prosumer collectives. Another work by Acosta [114] investigates how RES prosumer collectives (which they refer to as “integrated community energy systems”) hold the potential to be more inclusive and environmentally friendly energy systems while offering direct benefits to local economies. Thus, the focus of RES prosumers as a “commons” is critically concerned with inclusivity, while environmental sustainability principles such as sufficiency are also relevant. Within this literature, recent studies focus on the possibility of alternative system innovations that tackle societal issues by moving beyond mainstream market and organisational configurations while also employing innovative engineering tools (i.e., open-source software, sustainable technology) under the concept of “dynamic energy commons” [115].

The focus on sufficiency is central to research into the “autarky model”. This model implies a different concept of sufficiency as a condition for being “off-grid,” and therefore “self-sufficient”. Within this literature, there has been a proposal for a “sufficiency indicator” for individual household prosumers. Here, sufficiency is defined as a “personal balance of not consuming more than what is needed but also not consuming less” (p.195) [100] to describe a qualitative degree of self-sufficiency based on citizens’ ratings. Another related study argues that acceptance of RES prosumer systems is likely to increase if aspects associated with an autarky model, such as independence and

self-sufficiency, are also valued [101].

Additionally, RES prosumers research with a focus on inclusivity concerns articles on RES prosumer models adopted by Indigenous communities [98], highlighting potential benefits such as increased energy autonomy without specifically addressing sufficiency other than the importance of being “self-sufficient” [99]. However, being self-sufficient entails attention to resource use and consumption dynamics. Therefore, RES prosumer projects in Indigenous communities equally bring together concerns of inclusivity and sufficiency.

Lastly, an emerging literature on energy justice [45,79] and energy citizenship [11,44] is driving the discussion on inclusivity. Specifically, the notion that new energy infrastructures and the design of energy systems can perpetuate injustices is noted with the proposed concept of “flexibility justice” [39], and how different sociotechnical factors can impact citizens’ ability to benefit on equal terms from RES prosumerism. Furthermore, studies on gender and RES prosumers are particularly concerned with how women can have a more prominent role in decentralised energy systems and cooperative investments [102].

Overall, the narrative of the last two decades can be summarised as starting from inquiries into the enactment of energy citizenship, to community energy understood as a grassroots (socio-technical) innovation, to research into regulated energy communities. Despite their increased institutionalisation, RES prosumer initiatives offer a thriving bedrock for inspiring innovations and new grassroots configurations (e.g., energy as a “commons”, and alternative blockchain communities). These innovations integrate interrelated sufficiency and inclusivity

concerns and practices within specific regulatory, socioeconomic, socio-cultural, and socio-technical contexts that frame the initiatives.

4.3. Exemplary cases

Exemplary RES prosumer initiatives identified through the narrative review illustrate relationships between prosumerism, inclusion, and sufficiency. In Europe, REScoops have been at the forefront of efforts to tackle energy poverty and foster energy democracy, which are important for energy inclusivity. One example is the SomEnergia cooperative [136], which adopted a series of measures to help tackle energy poverty concerns [137], while actively promoting tools for energy democracy. Created in 2010 in Girona, Catalonia, SomEnergia is the largest renewable energy cooperative in Spain. The cooperative operates as an energy producer (total production is 63.03 GW/h/year), through the collective investments of its 84.059 active cooperative members and acts also as an energy utility (with 118.333 energy contracts). Since its inception, SomEnergia has been a strong advocate for “breaking the existing energy oligopoly” [138], and actively participating in a “social movement” for a more transparent and democratic energy system [16].

To ensure full transparency and maximise the participation of its members, SomEnergia created its own digital platform (i.e., “Participa”) where all members can participate and collectively decide on energy issues. Aside from the annual general assemblies, cooperative members can participate on various occasions through the Participa platform and submit their proposals. The platform used an open-source code “Decidim” developed by the Barcelona municipality [139], which has also been adopted by other cooperatives in Catalonia with SomEnergia’s support. One of these cooperatives is SomConnexió, an innovative non-profit telephone and internet cooperative offering telecommunication services.

To tackle energy poverty, SomEnergia has put forward a series of measures, including developing capacity training programmes with municipal technical staff on energy efficiency and measures to prevent energy poverty; establishing agreements with municipalities and their social services to prevent energy supply cuts when consumers are not able to pay their electricity bills; and providing voluntary donations through the cooperative’s local groups to fund actions for preventing energy poverty [138,140]. Both the “Participa” platform and the cooperative’s strategies to address energy poverty are examples of the networked agency of this REScoop. These examples show that SomEnergia builds its identity as a socially fair and innovative energy provider and producer within Catalonia’s specific sociopolitical and socioeconomic context. Nevertheless, the example also indicates that sufficiency is not a central concern for this REScoop.

Grassroots innovations are also leading inclusive and sufficiency-guided prosumer projects, as exemplified by First Nations in Canada. These communities are members of the Indigenous Clean Energy Network, which acts as a network of RES prosumers, and offers programmes for “clean energy capacity building and project development support”, promotes “indigenous youth clean energy leadership” and aims to “build connections for clean energy impact”, “sharing knowledge, and foster collaboration” [141]. Aside from its capacity-building workshops, the network holds a podcast entitled “Decolonizing Power, ” where indigenous nations share their experiences about “energy sovereignty” and “the protection of Mother Earth”. The network also organises annual gatherings with Indigenous leaders and energy experts to “foster essential strategies to advance with a clean energy transition” and has the explicit goal of increasing “indigenous inclusion and leadership in clean energy” [141]. According to the network, there are circa 200 active RES projects of First Nations in Canada, implemented in partnership with energy companies. In addition, between 1700 and 2100 micro- or small-renewable distributed systems are operational in First Nation communities. Thus, key principles for Indigenous participation as RES Prosumers include “decolonization,” but also efforts towards more inclusive systems in which Indigenous communities not

only participate but seek to assume a leading role in Canada’s decarbonisation efforts.

Another example of a grassroots innovation, is the development of “modular solutions” by the Tamera eco-village in Portugal, such as “solar kitchens”, that can be easily adapted and implemented in vulnerable communities and spaces (i.e., “refugee camps”) [142]. Tamera eco-village is a socio-ecological experiment guided by principles of non-violence and striving for global peace. Therefore, all its activities, including its innovative use of renewable energy technologies, are grounded in an overall mission to contribute to a “regenerative and non-violent” culture, with close attention to the sustainable use of local resources [143].

5. Discussion

Sufficiency and inclusivity concerns and practices are not frequently an explicit focus of RES prosumer research, yet both are often implicitly considered in the ways prosumer projects are described, e.g., by referring to the “sustainability” of renewable energy cooperatives that aim to collectively decide on renewable energy investments that will be sufficient to power their members’ consumption [102,142]. There is evidence that sufficiency and inclusion are not always guiding principles for several RES prosumer initiatives, from the most professionalised organisations such as REScoops, to local grassroots innovations. However, there are also limitations to the evidence provided by this work, since this study is based on a literature review and does not investigate first-hand the motivations, perceptions, and practices of those involved in implementing diverse types of prosumer projects. Nevertheless, this review offers some key findings that are relevant for understanding how both sufficiency and inclusivity are concerns for RES prosumer practices across the world.

European policy and legislation for prosumers established regulatory frameworks included in the European Clean Energy Package [111], and more recently its “Fit for 55 Package” [144], with a focus on “renewable energy communities” and “citizen energy communities”, which are meant to ensure environmental, economic, and social benefits to the participating communities rather than being profit-driven [111]. Given their focus on producing environmental benefits, such prosumer communities appear well suited to integrating an ethos of sufficiency, although this study’s results indicate more can be done in EU legislation and other jurisdictions to cater for energy sufficiency. These prosumer communities are also partial to inclusionary practices, as RES prosumer projects may be initiated and led by different actors – e.g., local communities, municipalities, and start-up companies –, who may be shareholders of these communities. Non-European regions could benefit from replicating these regulatory frameworks while taking stock of lessons already learned in Europe on some of the shortcomings of its innovative legislation. For instance, while new energy communities are perceived to potentially help address problems such as energy poverty, there is still little practical guidance on how to achieve this [15]. Therefore, there are significant improvements to be achieved.

Several studies have questioned whether poor households can easily become prosumers [15]. Cooperatives are perceived as having a leadership role because cooperative members are more likely to provide free electricity to energy-poor households [130]. In the case of energy communities, the surplus income needed for individual investments in new renewable energy self-consumption installations may be sustained by higher-income citizens [130], and/or through other mechanisms such as participatory budgets, where local governments play a facilitating role [14]. In this scope, European countries would also benefit from learning from the experiences of grassroots innovations, such as Indigenous communities in Canada [145].

However, the value of RES prosumerism for achieving broader climate change targets and energy policies relies on the assumption that distributed systems will be dominant in low-carbon energy systems, yet large-scale systems are gaining increasing political focus [146,147]. This

raises the question of whether prosumerism is a policy priority and to what extent principles of inclusion, such as energy democracy, are possible when large-scale, utility-driven investments are favoured in meeting climate and energy policy goals [14]. These questions are relevant for Europe and other regions of the world, where localised prosumers projects may become an exception to large-scale energy infrastructure [78,148]. In such circumstances, even if catering to sufficiency and inclusion, RES prosumerism may remain a niche innovation with little impact on the achievement of climate targets.

Furthermore, the development of prosumer-based distributed energy systems is still in its infancy, with several regions around the globe lacking the basic requirements in terms of grid stability and digital infrastructures to implement smart systems, which poses a problem for inclusion from a global perspective. A widespread adoption of these systems may not be possible without large investments in the grid infrastructure of the Global South. Nevertheless, in rural regions, dependent on less efficient and centralised energy supply models [77, 149], RES systems tailored to local consumption could build on synergies with digitalization policies, incentivizing the development of new local businesses in coordination with sharing economy activities (e.g., food production, common spaces in buildings) [150]. Hence, fostering the much-needed regulations for a sharing economy equally offers an important context for enacting sufficiency practices while enabling a more inclusive adoption of RES prosumer systems worldwide [151].

In industrialized countries and regions, sufficiency can be equally a guiding principle in technological development through blockchain applications capable of optimising energy sharing within energy communities through automated real-time tracking and trading between community members [46,124]. Here, sufficiency would also depend on the outer boundaries set for access to resource use and on avoiding rebound effects (i.e., a reduction in expected gains in sufficiency due to other behaviours or systemic responses) that create a new set of services to be covered [152,153]. What is more, the wider ecological impacts of digitalization can aggravate environmental burdens if energy sufficiency is not considered [154].

Thus, collaborative and sharing models seem to be relevant for implementing sufficiency in practice. Participants in energy community projects may collectively agree on how they optimise the sharing of the energy they self-produce [155], or collectively manage the use of battery storage [122], engage in the sharing of electrical vehicles [151], sharing living spaces, and/or agree on new co-created demand-side management tools [156]. These patterns of consumption and production can meet sufficiency goals and are highly relevant for research into “energy commons” [115].

Collaborations have already been established for the replication or upscaling of some RES prosumer models [102]. For instance, many new energy cooperatives in Europe benefit from the support of established networks such as REScoop.eu, the Community Power Coalition, or older energy cooperatives [63]. Examples of synergies may be related to organisational forms (e.g., a local initiative may benefit from becoming a local cluster of a larger cooperative); to the co-development of specific products, such as open-source software platforms; or to capacity-building programmes on opportunities to collectively access new funding [7,124]. Financial participation through crowdfunding and crowdending, as well as new policies such as taxation on the profits of large-scale solar or wind energy farms [72] to be reinvested in community energy projects, offer possibilities for more inclusive participation that can benefit from innovative regulations [157,158].

However, one key challenge relates to the topic of energy flexibility. In peer-to-peer system configurations powered by multi-scales of solar and wind energy production [84], the capacity to be flexible is affected by a wide range of sociotechnical factors [39]. Flexibility entails, for instance, the possibility of adapting everyday life routines to (e.g., solar) energy availability. From a prosumer perspective, the capacity to be flexible is thus dependent on various factors, such as gender, working routines, household composition, energy storage capacity, age, wealth,

and overall everyday practices [39].

Moreover, motivations for becoming a prosumer and the social acceptance of new technologies (e.g., peer-to-peer, demand-response) are not determined by technological aspects alone but also by the ability and opportunity to participate [159]. This is a critical and still under-research aspect of prosumer households. When considering the need to draw increased flexibility potential from the grid, policymakers must assess prosumers to be as equitable as possible concerning their flexibility capital [39]. This point has also been elaborated by Korsnes and Throndsen [160] who show how prosumer pilot projects in Norway have a way of prefiguring certain types of solutions that happen to be beneficial for rich segments of the population. Preferred solutions are typically high-tech and capital-intensive and can therefore be more appealing to those households that are already affluent, typically owning an electric vehicle, often a SUV, and having rooftop solar PV installed. These emerging issues of “flexibility justice” offer an example of the relational and context-specific nature of RES prosumerism and its intersection with sufficiency and inclusivity. For instance, options for mainstreaming participation in the context of RES prosumerism need to consider housing infrastructures, with incentives for a diverse typology of ownership and land use that benefits the most vulnerable and less likely to own, or have a long-term rental of, the house they live in.

Access to prosumer-centred energy systems thus needs to be increasingly considered a common and shared good, enabling new social ownership and participation structures to emerge [115]. Citizens need to deal with complex financial, technological, and administrative requirements and the resources required to become prosumers [13]. These aspects largely exclude disenfranchised, vulnerable, and lower-income citizens and communities, who cannot meet basic criteria to even consider investing in solar panels for their homes [11,15], both in Northern and Southern Hemisphere regions. Indeed, the participation of more vulnerable and disenfranchised communities, young people, and women, including the right to have a vote in energy decisions, needs to be targeted by RES prosumer policies [13].

Overall, how RES prosumer projects prefigure practices based on sufficiency and inclusivity concerns is framed to some extent by local contexts. Nevertheless, innovations that foster collaboration (e.g., energy commons, peer-to-peer), including grassroots innovations and citizens’ willingness to and ability to participate in new energy projects, are likely to result in more inclusive and sufficiency-guided prosumer initiatives.

6. Conclusion

By drawing on a relational and systemic approach to renewable energy sources (RES) prosumerism, this review analysed the interrelation between RES prosumerism, sufficiency, and inclusivity. The study evidenced that inclusivity and sufficiency have not been major cross-cutting concerns across the variety of prosumer initiatives that exist. However, such concerns are more relevant for initiatives based on collaborative models and with a focus on sharing.

Particularly, prosumer grassroots innovation initiatives and peer-to-peer models focused on “energy commons,” are grounded in sufficiency and inclusivity concerns and practices. Conversely, European REScoops represent a wide diversity of initiatives, which do not always have these concerns. For instance, the inclusivity and sufficiency practices of REScoops are limited by the requirements to become a cooperative member and the capacity of the cooperative to manage its members’ energy consumption and encourage energy reductions.

Nevertheless, the intersection of RES prosumerism, sufficiency, and inclusivity in practice results from distinct points of departure. From the perspective of vulnerable communities and developing nations, catering for energy sufficiency equals reaching a minimum standard for well-being but also moving towards decolonized and autonomous energy communities. RES prosumerism offers an important socio-technical avenue for enabling sustainable energy solutions for communities with

little or no access to clean energy sources. In this context, prosumerism can potentially be more inclusive globally than other forms of centralised energy production, which have failed to resolve local energy access problems. Thus, grid infrastructure and digital infrastructure investments should be a policy priority to support grassroots and local prosumer initiatives in the Global South.

Conversely, in richer countries, sufficiency and inclusivity are framed by the possibility of citizens participating on equal terms in new smart systems. Key policies for RES prosumer initiatives, such as promoting energy communities, should set some limits on demand while not overlooking potential rebound effects and offering opportunities for citizens' democratic participation. An increased focus on sufficiency has also the potential to lead to more equitable solutions, with resources being better distributed. Prosumer policies for richer communities and countries should therefore encourage energy arrangements that support a collective move towards practices that entail reduced energy and resource use while narrowing the gap between rich and poor. This implies implementing rewards for achieving actual reductions, as well as getting funding for investing in energy efficiency measures for those who experience energy poverty [29]. Principles of sharing and/or recycling or reusing materials gain particular importance, since policies that enable and encourage new community practices – e.g., shared laundries, co-working spaces, etc. – in coordination with new RES installations make it more realistic for RES prosumers to meet sufficiency goals. It is equally valuable to learn how local governments and communities can promote “energy as a commons” through, e.g. tax incentives that encourage energy sharing models. In other words, RES prosumer initiatives could come with requirements that enable sharing and put limitations on total space use and total resource use.

In the absence of policies, European REScoops, and grassroots innovations may offer lessons learned for other regions of the world. First, European cooperatives have established a European federation of energy cooperatives (e.g., REScoop.eu), that fosters coordinated efforts among different prosumer initiatives, exchanging knowledge on new technological models for demand-side management, on the cooperative model and collective energy investment models. Second, the networked governance of grassroots innovations (e.g., Indigenous Clean Energy Network) can support the development of more inclusive prosumer community investment strategies.

A limitation of this study is the geographical focus of most articles reviewed (i.e., 218 out of a total of 241 focused on the Global North). The findings are equally limited by the method of study, which is based on a review of literature. Further research should thus include comparative analyses of case studies from different regions of the world, with a focus on Southern Hemisphere countries, with examples of grassroots innovations and other social innovations in the scope of RES prosumers. New studies should provide insight into prosumers' perspectives, motivations, practices, and challenges in participating in new smart, sustainable and decentralised systems. New research should equally focus on how to accommodate energy flexibility processes that prevent the exclusion of more vulnerable citizens and communities.

Lastly, future research should investigate how grassroots solutions together with top-down solutions can work in tandem to achieve RES prosumer models that accommodate both sufficiency and inclusivity: the first in terms of higher engagement (i.e., sharing solutions) and the latter in terms of promoting new models, including through alternative financing and the provision of community funds (e.g., revenues of carbon tax, revenues from large-scale renewable investments). Such studies should aim to improve current legislation for prosumers, as well as inform future legal frameworks, both in Europe and elsewhere, that can internalise energy sufficiency and inclusivity as guiding principles and by adopting stringent climate and energy targets.

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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