European Commission

JRC TECHNICAL REPORT

Prosumerism and Energy Sustainability

A Sociotechnical Perspective on New Forms of Prosumerism and Energy Sustainability in the EU

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2022

Joint Research Centre

EUR 30981 EN

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EU Science Hub
https://ec.europa.eu/jrc

JRC126571

EUR 30981 EN

PDF	ISBN 978-92-76-47146-2	ISSN 1831-9424	doi:10.2760/608826

Luxembourg: Publications Office of the European Union, 2022

How to cite this report: Korsnes, M., Labanca, N., Campos, I., Serrenho, T., Della Valle, N., Bertoldi, P., Prosumerism and Energy Sustainability – A Sociotechnical Perspective on New Forms of Prosumerism and Energy Sustainability in the EU, EUR 30981 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-47146-2, doi:10.2760/608826, JRC126571.

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Acknowledgements

Authors

This report has been written through a collaboration between several researchers. Paolo Bertoldi has had the overarching responsibility and coordination of the report, whilst the writing of the report has been done by Marius Korsnes with input to all the chapters, Inês Campos to Chapter 4, Nicola Labanca initially conceived the idea, worked on Chapter 2 and full review, Nives Della Valle and Tiago Serrenho provided full review. Marius Korsnes wishes to thank his colleagues at the Department of Interdisciplinary Studies of Culture, NTNU, for their support and for making it possible to take time off to write this report. He also wishes to thank the four experts interviewed for this report, namely Jouni Juntunen, Michael Ornetzeder, Noel Cass and Louise Reid, for sharing their highly interesting and useful insights on this emerging topic. Lastly, the authors would like to thank Emanuele Uboldi at the European Commission Joint Research Centre for excellent proofreading and typesetting.

Abstract

This report develops a sociotechnical understanding of energy prosumerism to investigate how energy prosumerism, as an alternative production and consumption pattern, can lead to actual reductions of energy and material resource demand. The report starts out by explaining what a sociotechnical perspective entails and what is meant by prosumerism. Thereafter, the report discusses how energy implications of prosumerism can be enlightened by the concepts of use value and sharing as well as by the study of historical changes that occurred in the delegation to machines and by studies in the area of thermodynamics and social metabolism. Then, it summarises already existing sociotechnical research on renewable energy generation and domestic energy use, focusing in particular on energy communities.

The different types of energy communities can represent specific types of sociotechnical innovations whose role in the energy transition and whose environmental, social and economic impacts are still object of study and debate. Thus, it is critical to clarify how new forms of prosumerism represented by collectives of citizens actively involved in energy production, consumption and distribution, are progressively gaining a relevant role in the energy transition. For example, it becomes important to achieve a better understanding of the meaning and typologies of existing energy communities, how these communities relate to new forms of governance and citizen involvement, to new business and financial models, to technological innovations, and how it can be expected they will contribute to the energy transition. The report discusses in particular how, over the past decades, community energy has taken many forms: from projects 100% owned by local communities to others that imply a co-ownership with the private sector and/or local authorities.

The report then delves into the matter of energy sustainability by explicating the concept of sufficiency and how it can allow achieving actual reductions instead of continued escalations of energy use. Finally, it concludes with the main findings that a broader and more nuanced understanding of energy prosumerism can provide a novel conceptualisation relating to energy provision and everyday life that can lead to future reductions in energy use, as well as to a more multifaceted policy response that moves away from business as usual and towards more variegated and radical propositions for achieving sustainable energy use in the future.

Executive Summary

This report develops a sociotechnical and broad understanding of energy prosumerism to investigate ways in which new forms of energy prosumerism can lead to actual reductions of energy and material resource use. Three central questions have guided this enquiry. First, the study aimed to discuss whether prosumerism can offer a more plausible pathway to sustainable energy systems as seen from a sociotechnical and complex systems perspective. Second, it specifically focuses on renewable energy source (RES) prosumers to understand how they can foster a more collaborative, sufficiency-based, flexible and decentralized energy system. Third, it critically analyses prosumers and new energy communities to understand the relevance of associated new European legal identities and the resulting ecosystems in fostering a more resource-efficient, democratic and sustainable energy system. These inquiries finally converge into a set of policy recommendations for sustainable energy systems.

The structure of the report is as follows. First, the report offers a sociotechnical and broad understanding of prosumerism (Chapter 2) before it summarises already existing research on energy social science and humanities relating to renewable energy generation and domestic energy use (Chapter 3) and energy communities (Chapter 4). The report then delves into the matter of energy sustainability by explicating the concept of sufficiency, and of achieving actual reductions instead of continued escalations of energy use (Chapter 5). Chapter 6 concludes the report with the main findings on how a broader and more nuanced understanding of energy prosumerism can provide for a novel conceptualisation relating to energy provision and everyday life that can lead to future reductions in energy use. Chapter 6 equally offers concrete policy recommendations, also informed by feedback from four interviewed experts. In particular, it points out how a narrow, techno-economic lens has the potential to generate wider inequality and thus also to make the transition towards more sustainable societies more challenging. On the other hand, it highlights how a principle of sufficiency can act as a counterbalance if it is used as an opportunity to include a broader segment of the population to take part in sustainable prosumer arrangements that aim at reducing energy use with a broad understanding of energy and society.

1 Introduction

We find ourselves at the crossroads of an ecological crisis, where the need for swift transformations of our production and consumption patterns is pressing. We face the daunting challenge of reducing greenhouse gas emissions while having to prevent further biodiversity loss and environmental degradation – at the same time as human populations should have the possibility to lead good lives globally. This triple challenge makes it critical to explore the potential of prosumerism and energy production and consumption as a way forward towards sustainability. Thus, this report investigates how new forms of prosumerism might impact energy consumption by looking into recent types of prosumerism and their potential to stimulate a more sustainable use of available energy sources, considering Earth systems' complex thermodynamics. The report is equally focussed on how some of these new forms of prosumerism can be fostered through additional policies and aims to draw insights on ways of improving energy sustainability.

Three central questions have guided this enquiry. First, the study aims to address how prosumerism can offer a more plausible pathway to sustainable energy systems by relying on a sociotechnical and complex systems perspective. Second, it specifically focuses on renewable energy prosumers to understand how they can foster a more collaborative, sufficiency-based, flexible, and decentralized energy system. Third, it critically analyses prosumers and new energy communities to understand the relevance of associated new European legal identities and of their resulting ecosystems in fostering a more resource-efficient, democratic and sustainable energy system. These inquiries finally converge into a set of policy recommendations for sustainable energy systems.

Recent European Winter Package legislation, specifically the recast of the Renewable Energy Directive (REDII) and the Internal Electricity Market Directive (EMD), provides definitions of self-consumer, as well as Renewable Energy Communities (RECs) and a definition of Citizen Energy Communities (CECs). Taken together, these definitions can lead in practice to new types of both physical and virtual energy projects at different levels of governance, involving individual and collective actors, covering a wide range of Renewable Energy Sources (RES) production, distribution, consumption and storage-related activities. Furthermore, while the two EU Directives and their definitions have been a steppingstone for the development of community energy, they have equally shed some uncertainty on what exactly can be expected from such a diverse universe of community-led action. This report will seek to characterise such diversity, based on a sociotechnical perspective and a clearer understanding of what prosumerism can mean for a new energy system.

As will be discussed in this report, prosumerism is not a new concept, but it has gained relevance in decentralized energy systems, particularly in efforts to achieve more efficient and collaborative (self-) consumption practices. The report starts by expanding on the sociotechnical perspective (Chapter 1) and its relevance as an analytical lens for understanding prosumerism and society, exploring how the concept of prosumerism and distributed and collaborative energy systems can converge towards higher levels of efficiency and sufficiency, and potentially lead to more sustainable social 'metabolisms' (Chapter 2).

The specific role of prosumers in relation to the transition to a RES-based system is further explored in Chapter 3. Chapter 4 examines the role of prosumers and their energy communities' ecosystems, following new European definitions, but also considering a tradition of community energy and renewable energy cooperatives in Europe. Specifically, it seeks to further distinguish RECs as place-based communities living in proximity to the RES installations (these communities taking the form of local associations, local cooperatives or being run by local SMEs or public authorities), and CECs, which can be virtual communities, such as the national renewable energy sources cooperatives (i.e., the so-called REScoops). The latter, in particular, challenges the typical large company utility-centred model of energy production, distribution, and consumption. Chapter 4 also expands on the relevance of the transposition of the Internal Electricity Market Directive (EMD) and its definition of CECs, given its major importance for large REScoops. REScoops, in fact, will be able to benefit from a targeted legal framework that accounts for their many citizen-driven and volunteering-based activities and provides a level playing field for their market integration. Despite the undeniable importance of RECs for galvanising and mobilising citizens' participation in the energy transition, CECs are no doubt the key framework for REScoops and can potentially support their transformative potential for a 'community-led renewable energy revolution in Europe' (REScoop.eu, 2021c). The extent to which this model can lead towards a more just energy system will largely depend on supporting policies that effectively enable more vulnerable and disenfranchised communities to actively partake in this "revolution".

Finally, Chapter 5 looks into critical aspects for sustainability, namely sufficiency, energy conservation and consumption reduction, leading to final conclusions and policy recommendations for a sustainable energy transition (in Chapter 6). This perspective goes beyond decarbonisation and towards effective reductions in energy use to make decarbonisation more compatible with resource limits of our planet.

1.1 A sociotechnical perspective

The approach taken in this report is a sociotechnical one, i.e., it implies studying the co-evolution of society and technology as inextricably interlinked (Bijker and Law, 1994). Technology and society are seen as two sides of the same coin, and the ways in which they change are always mutual and interdependent. The implications for studying energy impacts of prosumerism under this perspective are amongst others that:

1. The energy impacts of prosumerism cannot be understood only by investigating what occurs within a specific sector of current economies, be it manufacturing, energy production and consumption, or the digital economy.
2. A historical perspective, which shows the co-evolution of production and consumption over time, will be helpful in understanding how reduced energy consumption can be achieved. The reasons for this are quite simple. These transformations are happening in all economic sectors at the same time and are not primarily driven by considerations concerning how the energy consumption of human activities can possibly be kept limited. Their energy impacts originate, therefore, in any economic sector, and their main characteristics are more likely to be grasped when they are studied by trying to identify its recurrent aspects in the various sectors. This, however, can hardly be done without establishing in what respect new forms of prosumerism are actually new. What types of services are they providing, and are these luxuries or necessities?

In the context of the energy transition, a sociotechnical perspective provides the 'capacity to see the interconnections, mutual shaping, co-constitution, or coproduction of the technical, social and natural' (Hess & Sovacool, 2020, p. 2). As defined by Labussière and Nadaï (2018, p. 5), a sociotechnical approach is useful because it allows an exploration of 'the politics of processes that bring technologies into existence and the politics that is incorporated into the technologies and contributes to composing their social environment as they emerge'. Labussière and Nadaï (2018, p. 23-24) also list four implications of a sociotechnical approach that are also useful to recount here and that will become relevant throughout this report:

1. 'Efficient technologies are not given in advance, because efficiency results from the success of a technological proposition'. That is discussed in more detail in Chapter 2 and Chapter 5.
2. 'Public participation in the emergence of a technology is not an option; it is a precondition for innovation to work and efficient technologies to emerge'. This proposition is elaborated on in Chapters 3, 4 and 5.
3. 'Since efficiency is a matter of alignment, it is always possible that *things could have followed another course'*. This proposition is always useful to think with because the current different technological arrangements have been brought about due to the support of a variety of actors over time – and this might have been otherwise (see Woolgar & Lezaun, 2013).
4. 'There is thus an issue for social sciences in analysing the politics of technological change, that is, in following the way in which actual versions of technologies endow certain actors and not others with powers and capacities for action'. This last point is providing the rationale for this report, as it provides a view into the usefulness of prosumerism from a social science perspective.

1.2 The 'prosumer' term

Prosumer is the combination of two words: producer and consumer. The term was introduced by futurist Alvin Toffler in his book *The Third Wave* in 1980. Toffler held that in the 'Third Wave', the line between producer and consumer would be progressively blurred because of a return to production for own use. This implied taking a step away from production for exchange value, which was introduced during the 'Second Wave' when production and consumption were separated as part of the industrial revolution. Instead of producing for a market, society would return to something similar to the 'First Wave', the agrarian society, where people lived in cottages and produced mainly for their own use:

> *During the First Wave most people consumed what they themselves produced. They were neither producers nor consumers in the usual sense. They were instead what might be called 'prosumers.' It was the industrial revolution, driving a wedge into society, that separated these two functions, thereby giving birth to what we now call producers and consumers. (Toffler, 1980, p. 266).*

Accompanying the trend of reuniting production with consumption, Toffler (1980) imagined a 'de-massification' of society, where not only 'information, production, and family life, but the marketplace and the labour market as well are beginning to break into smaller, more varied pieces' (p. 231). That entailed that more work would be performed in the home or in what he called 'electronic cottages'.

More contemporary usage of the prosumer term is connected to Information and Communication Technology (ICT) and is especially tied to the increase in user-generated content on the Internet, often referred to as the Web 2.0, where YouTube, Twitter and Facebook are prominent examples (Ritzer & Jurgenson, 2010). This case is similar to the way in which prosumerism is conceptualised in energy research (which will be outlined in Chapter 3), as they both have in common a decentralisation of 'production', with the potential to reshape existing demand and supply relations. The various usages of the term will not all be explained here. Nevertheless, suffice to say that the prosumer term was coined as a term that was supposed to say something about the organisation of society at large and has later on been applied to different fields such as ICT and energy. This report will continue some of these discussions in order to get closer to an understanding of how the term and practice of prosumerism can be helpful in ultimately achieving reduced energy consumption.

2 Prosumerism and Society

2.1 Prosumerism, use value and concepts of sharing

Within the social sciences and humanities, social relations connected to the ways in which we produce and consume have been studied for a long time, and go back to classics such as Adam Smith, Karl Marx, and Max Weber. Since the term prosumer was coined, the theorization of prosumers appears to be dominated by the concepts of *use value* and *exchange value*. Toffler conceptualised the prosumer term as a critique of the market, extending back to Marx's notion of alienation of workers that did not own what they produced. Not owning the fruits of labour would lead to pure appropriation by capitalists as opposed to the more engaged transformation, which was associated with owning and shaping what was produced through labour. In short, labour and work were, according to Marx, of essence to human welfare, but private ownership could lead to alienation (Rosa, 2020, p. 22). In other words, production for exchange value could be accepted if it was not owned by a capitalist. Production has typically been at the centre of analysis for both the general population and academics, and only after the Second World War did a focus on consumption start to emerge (Ritzer, 2014). Consumption was seen as an outcome or result of work and not of value in itself. From the 1980s, the idea that consumption and production were highly interrelated started to emerge. As pointed out by Douglas and Isherwood (1979, p. 4), 'Consumption has to be recognized as an integral part of the same social system that accounts for the drive to work, itself part of the social need to relate to other people, and to have mediating materials for relating to them'. That connects with the idea of use and exchange value because 'use value' typically has been thought to relate mainly to individuals, whilst 'exchange value' has been connected with a social relationship (McNeill, 2020). The social was mainly relegated to the field of production, whilst consumption was thought of as more pertaining to the individual. Where Marx stated that 'production … creates the consumer', the idea that consumption itself is nested in a web of social practices and needs that change over time was not recognized (quoted in McNeill, 2020). Nevertheless, as pointed out by consumption researchers, use value is subject to change and cannot only be seen as something that covers needs that are there *a priori*.

As theorized by Ritzer (2014), there is no such thing as pure production or consumption. Each always implies the involvement of the other. For this reason, Ritzer develops a prosumer continuum from prosumer-as-producer on the one end to prosumer-as-consumer on the other, along which all forms of production and consumption occur as forms of prosumerism. Such a continuum makes it clear that acts of prosumerism can contain more of an emphasis or impetus on the producer side or the consumer side. For instance, those that produce cars or computers also need to consume time and resources to produce their desired item, and those that want to consume a hamburger must read the menu and often line up to order their product. The way in which IKEA has made use of the extra work of consumers, e.g., to unpack and build their own furniture, makes the prosumer-as-consumer distinction clear. In this understanding, novel ways of prosuming involve movements along the 'value chain'; producers either "do more", i.e., expand their services (e.g., home-delivery, ready-made food or similar), or consumers "do more" (e.g., building your own furniture).

This can also be seen as part of the surge that has been seen recently in social media and online content production, which has made certain researchers more aware of the potential downsides of the prosumer trend. The present-day situation has, for instance, been described by Ritzer et al. (2012, p. 383) wherein the 'ultimate social factories are the Web 2.0 sites where prosumers simultaneously consume and produce ideas on, for example wikis, blogs and social networking sites'. Some warn against 'prosumer capitalism' that rewards unpaid rather than paid labour, offers products at no costs, and that can be exploitative and alienating (Ritzer & Jurgenson, 2010; Comor, 2011). A similar sentiment is expressed by Humphreys and Grayson (2008, p. 11), who argue that prosumerism means that a consumer is producing exchange value for companies:

> *The true potential revolution in consumption/production is occurring in those increasingly frequent instances in which consumers are being asked – and often are willingly agreeing – to take over steps in the value chain that create exchange value. That is, they are helping companies to be more successful in the marketplace.*

Examples of this are if a company asks their customers for advice about how to best market a product or asks customers to suggest designs that the company can later use. In a critique of the concept, Comor (2011, p. 322) points out that Toffler proclaimed a very individualistic idea, a narrative that would further entrench a 'now atomized polity'. According to Comor (2011, p. 320), the problem is the focus on exchange value as an output that requires and reproduces a market-governed and profit-oriented system: 'Beyond the prosumer's economic exploitation, if prosumption is primarily about making money, existing material relations are perpetuated'.

Comor then points out that a fundamental change in the economic organization of society will come about if prosumers work or create 'primarily social or intrinsic needs rather than for exchange'".

The discussion on use value and exchange value appears to boil down to an understanding connected to the role of the market and capitalism. Critics of capitalism will be suspicious of exchange value, whilst proponents will think that it is fine. If prosumers generate use value for themselves or others, they can represent a positive change, but if they generate exchange value for companies, they are exploited and alienated. Nevertheless, the separation into these two types of value might hide more than it reveals. Ultimately, it seems important to ask how these values are constituted, how do they change, and through what relations and practices? For instance, what is use value and exchange value in the case of blogging: is the use value connected to the process of writing itself, perhaps? And would exchange value be connected to amounts of 'clicks' indicating how much traffic and views a site gets, which could be given exchange value in the form of advertisement? As we see, the concepts of use value and exchange value may very well be red herrings that take the focus away from what is going on: energy is being used to cover a need that is socially constructed, and changes over time. We will return to a deeper discussion on needs, prosumerism and the concept of 'sufficiency' in Chapter 5.

Another way of interpreting prosumerism is that new ways of organizing production and consumption may lead to new consumption patterns. This could, for instance, be observed in what is termed the 'sharing economy', which has increased in popularity in the past ten years. As pointed out by Botsman and Rogers (2010), sharing has been part of human nature since the very beginning. In the Stone Age, tribes would hunt and gather in groups because collaboration made it easier to catch an animal. This collaborative behaviour continued as human civilization started farming land by sharing equipment, building barns, harvesting crops, and defending the land. Some researchers believe that cooperative behaviour is not only learned but also has an evolutionary component (Pennisi, 2005). That particularly makes sense when examining the ways in which humans can organize into larger collectives that require a common agreement about the world, and a constant reproduction and circulation of narratives about the world. The sharing economy can nowadays be said to be an umbrella term that covers many recent online-based initiatives that can change the way society makes use of things, space, skills, and time.

Juliet Schor (2014) divides sharing economy activities into four broad categories:

- Recirculation of goods, which includes online marketplaces like eBay or craigslist,
- Increased utilisation of durable assets, where examples are Couchsurfing, Airbnb or car-sharing initiatives,
- Exchange of services, as exemplified by initiatives such as LETS, Task Rabbit or ridesharing / hailing services such as Uber,
- Sharing of productive assets, including initiatives where assets or space is shared in order to produce rather than consume, such as shared working spaces.

To be sure, it is not clear whether these sharing platforms represent a positive change in income distribution, equality, and welfare, and whether they will have beneficial environmental impacts (Frenken & Schor, 2017; Schor, 2016; Schor et al., 2016). One much-debated question is the role of the ridesharing app Uber, a service where literally everyone who owns a car can become a personal driver, which often charges less than the local taxi services. Concerns relating to workers' rights, long work hours and low salaries are reasons why many call apps such as Uber a 'race to the bottom'. Therefore, it still remains to be seen whether these various initiatives can be said to be real alternatives to the ways in which the society produces and consumes, or if they are simply generating more work – or lead to higher consumption. Cases with, for instance, Airbnb have shown that instead of renting out apartments that have idle space, local 'entrepreneurs' have purchased centrally located apartments for rental through Airbnb, making it more expensive for local inhabitants to live in the city centres. Other questions are connected to payment: is it really 'sharing' when people charge a fee for whatever they share? And what about inequality? This also raises the issue of flexibility capital and justice, aspects which will be discussed more in detail in Prosumers and domestic energy use.

2.2 Prosumerism and delegation: a brief historical perspective

As already mentioned, prosumerism is nothing new, and people have always contributed to producing what they consume. A very powerful and still largely diffused social imaginary concerning the possibility of entirely delegating human activities to machines seems, however, to play a central role in impeding to fully acknowledge this simple fact ([1]). People contribute to producing what they also consume when nature, other people or machines apparently do the entire job. Consumption always happens alongside production and vice-versa. Every consumption act (e.g., eating an apple) entails a production act (e.g., apple mastication) that enables consumption and cannot be separated from production, in the same way as every production act takes necessarily place through the consumption of some resources. The relationship and link between these two dimensions of human activity have however changed over time. These changes are reflected in how delegation to machines has been imagined during different historical ages and have had deep implications on the impacts of human activities on energy and natural resources in general.

Following seminal studies undertaken by Ivan Illich, Labanca (2017) argues, for example, that mass production became actually conceivable starting from the 12th century when the social imaginary developed around human artefacts used by people during everyday life underwent a key metamorphosis that changed these artefacts into *instruments* that can be used by *any* person to achieve abstract and predefined *ends*. Contrary to what usually assumed, mass production has not only been enabled by the introduction of machine tools and techniques that made it possible to produce interchangeable parts since the mid-19th century (see, e.g., Hounshell, 1984). What enabled mass production was also the social imaginary that started developing around human tools during the first decades of the 12th century. In this period, the previously predominant idea that conceived tools as entities shaped by the specific body and person using them started receding into a kind of background ([2]). Rather than in technical advancements, the social conditions that enabled mass production also have to be found in the transformations that made it possible to imagine human tools as autonomous entities whereby any person could in principle produce specific outputs. The invention of human instruments –testified by the first catalogues that started describing these artefacts during the 12th century, created a kind of *distality* (Cayley, 2005) between material objects and bodies using them. Through this imagined separation between persons and their tools, it became for the first time possible to categorise people as users while production and consumption/use of material artefacts could start becoming more and more independent. The diffusion of strange and new figures installing and repairing mills and connected machineries throughout north-western Europe during the 12th century is another phenomenon that generated and was generated by this separation. Eventually, this separation also certainly contributed to creating the present social imaginary of autonomous machines acting to pursue their own ends.

Another radical change in how delegation is imagined occurred then during the mid of the 19th century with the social transformations that took place around the large-scale diffusion of combustion engines and the invention of the energy concept. During that time, new ideas and scientific concepts about nature and combustion engines changed the universe into a gigantic reservoir made of a single, infinitely transformable, and a degradable but not destructible entity that was named energy. At the same time, *motors* became another central metaphor whereby nature and human artefacts started being imagined. If instruments have taken with them representations of nature and societies in terms of clockwise reversible mechanisms, transformations occurring with the diffusion of combustion engines made human action dependent on the provision, and optimised consumption of specific and scarce resource inputs. Energy became the universal fuel of human activities, which could be represented in terms of measurable inputs and outputs. Production and consumption could be connected to balance sheets, and societies could be re-organised in this way around the energy conservation principle.

According to Labanca (2017), a third radical transformation affecting delegation and human agency took then place during the mid of the 20th century. This latest change has led to the diffusion of a new kind of artefacts generally subsumed under the category of information and communication technology (e.g., personal computers, smartphones, computer servers, audio-visual systems, etc.). These new kinds of artefacts can be characterised in a fundamental way by the fact that single and same material objects are produced to be used by any person to perform an *ever-increasing* number of functions. In so far as, e.g., a computer can be used by any person to send emails, write a text, purchase products, call other persons, etc., this computer cannot be considered anymore as an instrument that can be left somewhere when not needed. Due to such an increasing number of functions, a computer becomes more like a human prosthesis that is integrated into the body and to which people have to stay "attached" for more and more time during daily life. The prosthetic nature of single

([1]) Charles Taylor defines social imaginary as 'the ways people imagine their social existence, how they fit together with others, how things go on between them and their fellows, the expectations that are normally met, and the deeper normative notions and images that underlie these expectations' (see Taylor, 2004, p. 23).

([2]) What might be defined as an inter-specificity existing between the person using an artefact and the artefact itself would have been so high to make a distinction between these two elements impossible or irrelevant before the 12th century. For example, in relation to hammering, no verbal distinction could be made between the arm holding the hammer and the hammer itself and a single word ("organon") was used to indicate both the hammering unit constituted by these two entities and each of the two entities. See Labanca (2017) for further details in this respect.

artefacts could emerge only around a series of changes which affected how information has been conceived since around the 1940s. Whilst before that time, information could not be imagined without a person reading it (i.e., information could exist and make sense only in conjunction with a human reader), developments and scientific advancements occurred with cybernetics have progressively changed it into an autonomous and measurable entity that alone can regulate the functioning of organisms, machines and people. It was this change in how information is imagined that made it possible to realize a new kind of integration between persons and artefacts. That should not be confused with integration established before the 12th century, exactly because of the new role played and the new nature acquired by information. Human-machine systems created through computer technologies rely essentially on a double interface whereby a double translation is constantly and actively performed through this new kind of coded information. A first interface translates and reduces acts accomplished by machine users into codes and messages that can be processed by the machine and translates codes generated by the machine into inputs and messages that can be understood by the user. A second interface is instead responsible for interactions with the environment where the human-machine system act and translates inputs from and output to this environment into information flows.

This new kind of information and the approaches that can be developed to elaborate it changed humans and machines into integrated systems whose functioning and identity consist in the generation of information feedback loops. The loss of distality associated with the creation of human-machine systems also makes the conceptual category of the *person* and the distinction between subjects and objects meaningless (Hailes, 1999). Moreover, this also represents the hallmark of a loss of persons' control over the material objects they interact with. Changes induced by this latest transformation of required human competencies are manifold and include, among others, what has been named a progressive shift towards their *IKEAization* ([3]).

Further elements to understand how the social changes accompanying the diffusion of information technologies affect prosumerism and the associated implications for energy sustainability of human activities will be discussed in the following sections. However strange it may seem, one of these elements is clearly reflected in the thought experiment imagined by physicist James Clerk Maxwell in the 19th century, and how this experiment allows establishing an equivalence between available energy units and the new type of information discussed above.

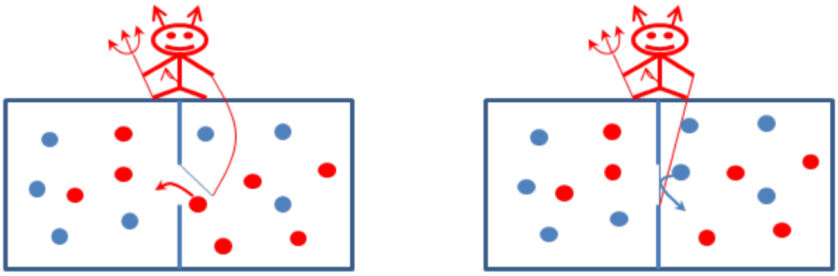
2.3 Prosumerism and Maxwell's Demon

Maxwell's Demon is an imaginary being that physicist James Clark Maxwell thought in 1867 (Rex, 2017) to suggest how the second law of thermodynamics might hypothetically be violated. This law is usually explained to students by referring to two chambers filled with the same gas. The chambers are thermally insulated from the external world and are possibly separated by a small door. Simply stated, the law establishes that, whatever the speed and temperature distribution of gas molecules in the two chambers, these gas molecules will always achieve a situation of stable thermal equilibrium where their average speed and temperature is constant all over the chambers, provided these molecules can transit from one chamber to the other. Alternatively stated, the second law of thermodynamics establishes that in a state of thermal equilibrium, it is impossible to observe situations where the average temperature and speed of the molecules registered in the two chambers can differ for sufficiently large amounts of time.

To explain how this law might be violated, Maxwell imagined a small demon able to selectively close and open the dividing door based on available information about the speed and position of the molecules in the two chambers (see Figure 1). This demon would hence be able to violate the second principle of thermodynamics by changing the gas state from a state of stable equilibrium where the average temperature and speed of molecules is constant all over the two chambers to a state where the temperature in one chamber (e.g., the left chamber) is constantly higher than in the other, this indicating that the entropy of the whole insulated system would have decreased.

([3]) This term has been used, among others, to refer to the Protestant work ethic inspiring the IKEA founder Ingvar Kamprad as based on a customers' 'diligent commitment to picking up their own furniture, carrying it home and making it themselves' (see Blackshaw, 2017, p. 88). According to the author, this ethic would have hardly espoused mass production and mass consumption without information technologies and the kind of automated and "do it yourself" approaches to work and leisure they have enabled.

Figure 1. Graphical representation of the Maxwell Demon selectively opening and closing the door separating two insulated chambers filled with the same gas.



By opening the door only in case of gas molecules passing nearby with speed higher than the average (i.e., the molecules in red), this demon could allow these molecules to transit from the right side to the left side and cause, in this way, an increase in the temperature of the gas in one chamber compared to the other, this apparently implying a violation the second principle of thermodynamics.

Source: JRC, 2021.

Maxwell's thought experiment has been the object of heated debates and has been highly contested. The main objection raised by physicists of his time was that Maxwell's interpretation of his experiment outcomes did not consider the amount of energy spent to generate and provide the information needed by the demon-door system to operate. Their point was obviously that the second principle could not be violated when this energy amount is properly taken into account ([4]).

Rather than its actual capability to demonstrate that the second principle of thermodynamics can be violated, the most fascinating aspect of this thought experiment is that it implicitly indicates that the creation of an immaterial entity like information must necessarily entail the consumption of finite energy amounts. Experiments conceived over the last 140 years to verify whether Maxwell was right have always shown that the second law of thermodynamics is not violated when the amounts of energy needed to generate and distribute information are properly taken into account (Rex, 2017). The main lesson to be drawn from these failures is that what might be interpreted as an information induced increase of order and efficiency in a part of an insulated system has so far always resulted from the consumption of amounts of energy that were initially not considered. When this energy is taken into account, it has so far always become evident that the entropy of the overall system has actually increased, and the second principle of thermodynamics has not been violated. This lesson is particularly important when applied to sociotechnical systems because transformations in part of these systems might correspond to local energy efficiency improvements implemented by actors who benefit from them in economic, environmental, and social terms. These local efficiency improvements, however, might not necessarily correspond to a reduction in energy consumption at the system level when all the consumption sources (including those associated with the creation and distribution of information) are included in the energy balance. Energy impacts associated with the generation and distribution of information are typically very difficult to assess and tend to be underestimated by energy analysts due to the immaterial nature generally attributed to information.

The last century has witnessed the birth and large-scale diffusion of information technologies which have radically changed previous approaches to goods' production and distribution. Information networks have made it possible to conceive distributed production and supply systems that allow avoiding producing large *stocks* of materials by enabling the implementation of on-demand production systems that activate production and distribution only when demand for specific goods is identified (Forrester, 1961). So-called smart manufacturing approaches employing computer-integrated approaches allow nowadays generating high levels of manufacturing adaptability, to implement rapid design changes and optimize the supply chain while reaching high levels of efficiency and recyclability (Shipp et al., 2012).

Benefits generated by associated improvements in economic, energy and resource efficiency represent most probably the main drivers of this quite recent evolution of manufacturing systems in so far as stocks production is minimised along the way ([5]). Thanks to information feedbacks, stocks of goods as wells as of constituting material and energy sources are indeed being progressively substituted by funds ([6]). Rather than by the

([4]) For an historical overview, see Rex, 2017.
([5]) Storage and creation of energy material stocks represent inefficiency for various reasons. Material, information or any other resource that is stored can remain unused, degrade or result unfit to an ever-changing demand and environment, or result more expensive compared to a situation where the production of these resources can in principle be activated on demand.
([6]) Funds are resources whose utilization requires duration, whereas stocks can in principle be consumed at will, without any specific rate constraint. On this point, see Georgescu-Roegen, 1971.

accumulation and processing of material and energy sources to be used at a later stage, human activities are being progressively re-organised by creating information and distribution networks whereby demand and supply are being changed in such a way that they can be constantly monitored and dynamically matched by minimising local inefficiencies linked to storage. The same dynamics of inefficiency reduction to be achieved through information and distribution networks are at stake with energy transitions nowadays envisaged by researchers and policy makers. It is indeed unthinkable to assume that amounts of fossil fuels currently needed by societies can be substituted by equivalent amounts of renewable energy stocks. That is, among others, due to huge amounts of energy that would be lost in the storage processes involved in stocks production: most of the renewable energy sources currently available are indeed highly fluctuating and geographically dispersed. This problem can only be bypassed by assuming that future intelligent information and distribution networks will allow matching energy demand with renewable energy supply by relying as much as possible on processes of transformation and distribution of available renewable energy sources that do not involve extensive creation of energy stocks ([7]).

What information and distribution networks are doing and are supposed to increasingly do in the future is what Maxwell's Demon was supposed to do in the conceptual experiment imagined by Maxwell. Thanks to information about available demand and supply, they potentially allow reducing entropy increases (and they hence increase efficiency) by reducing the amount of energy and material stocks that must be created within consumption and production cycles (i.e., they allow substituting energy and material stocks with funds & information flows). In the same way as Maxwell's Demon seems to be able to create order by redirecting punctual energy and material resources and bypassing equilibrium states, these information and distribution networks seem able to efficiently minimize storage needs based on:

1. Available information about where potentially highly dispersed demand and supply are localised,
2. Their supposed capability to constantly match this demand and supply.

The amount of energy that could be saved in this way might, in principle, be estimated. Taking a quite simple case as an example, we could, e.g., assume to estimate the amount of energy that can be saved by substituting hot water storage tanks with on-demand water heating systems relying on sufficiently large information and distribution networks using fluctuating renewable energy sources available in the environment. However, this kind of estimate requires a systemic perspective where energy impacts of information and distribution networks are duly considered and might be affected by great uncertainties. They could then result highly misleading in so far as they cannot take into account the performative and transformative dimensions ([8]) of information and distribution networks and how these contribute to creating additional demand and needs for additional supply. Possibilities of reaching higher numbers of people over wider geographical areas associated with the expansion of these networks represent, for example, a practically irresistible push to the creation of additional demand and hence of needs for additional supply. Moreover, mentioned performative and transformation dimensions generally emerge within competitive and global market settings and determine needs for additional mobility that are typically responsible for further additional energy consumption. Described storage reductions can indeed only be achieved when final product suppliers can rely on the possibility of choosing among different providers of raw materials and product components. This situation entails the creation of highly distributed and competing production chains that can be activated *on-demand*, and involves longer distances along which material products have to travel before reaching their buyers. By enabling consumers to become also producers of goods, Maxwell's Demon represented by discussed information and distribution networks makes it then harder and harder to distinguish between production and consumption (see Figure 2 for a schematic representation of how information and distribution networks are spatially reorganising consumption and production activities). Altogether, these transformations generate, therefore, formidable challenges for any quantitative assessment concerning the energy impacts associated with the diffusion of new forms of prosumerism discussed in this report.

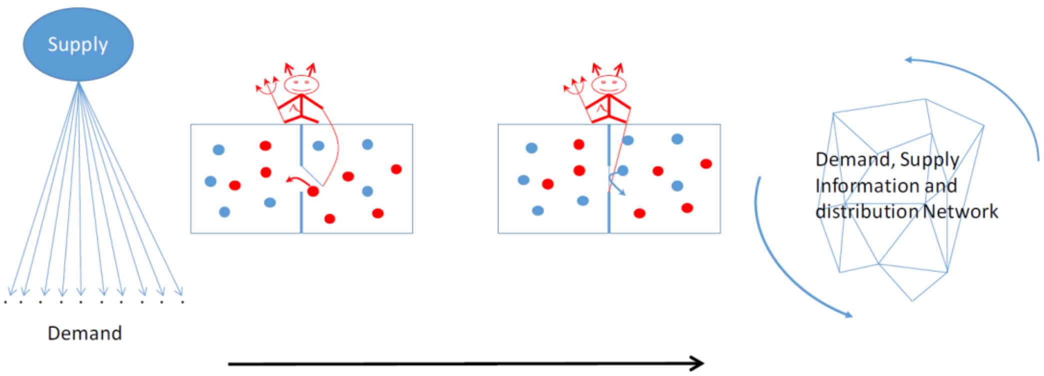
Despite these challenges, Maxwell's Demon reminds us that the creation, distribution and maintenance of information come at a cost. Integration into wide information networks has made nowadays possible to become

([7]) Actually, another necessary assumption to imagine that energy transitions will materialize is that current levels of efficiency in end-use energy consumption will markedly increase. On the role of energy efficiency in future energy scenarios, see for example estimates included in a recent IEA report (IEA, 2020).

([8]) The term "performative" is used here to describe the capability of an implemented system of solutions to change the reference or business-as-usual conditions, this generally making the assessment of the impact of their implementation very hard. These difficulties are quite common, e.g., in the field of energy efficiency where the impact of the installation of given efficient solutions (e.g., LEDs) is estimated by assuming that this installation will not change demand (e.g., number of light points in the houses, type of lighting services requested, etc..).

more flexible and agile in reacting to new external inputs by contributing to progressively dismantling existing rigid assets that might obstacle the establishment of new relationships whereon human activities have become increasingly dependent. These networks rely on surveillance technologies in principle capable of identifying or establishing relationships and information feedbacks among the constituents of any aggregate (from the most microscopic to the most macroscopic entities that can be detected in nature or produced in societies) while potentially enabling the monitoring of their evolution through the continuous generation of comprehensive snapshots ([9]). The active use and generation of this information feedbacks is what is radically changing the nature of human labour, health, leisure, transport, etc., and the way in which they are being organised and generated. Efficiency increases achieved in this way should, however, not induce neglecting energy and material resources necessary to create and maintain information flows. The more material and competence stocks are generally reduced by relying on information and distribution networks, the more the energy and resource burden represented by these networks increases. We should avoid assuming that the second principle of thermodynamics can be violated in the same way as Maxwell thought.

Figure 2. Schematic representation of the transformation in demand-supply systems induced by information and distribution networks.



Source: JRC, 2021.

2.4 Prosumerism and social metabolism

Existing interrelations between production and consumption can finally be studied also by taking the concept of social metabolism developed by complex systems theorists as a reference ([10]). This notion relies on some key concepts of the theoretical framework represented by complexity, some of which have been already generally discussed and might be worth describing briefly in some more detail. Complex systems theories conceive any aggregate of interacting parts (including human beings interacting with any material object or technology) as a system made of a series of incredibly intricate and interconnected circuits where information, energy, and matter flow. Therefore, any boundary or distinction between humans and non-humans has no relevance in the descriptions of the dynamics of these systems. Energy, for example, is assumed to flow in the same way and according to the same physical laws, no matter if it flows between inert objects or between human and non-human entities. Complex systems theories, therefore, merge and integrate human and non-human parts into the feedback loops of their networks. These flows and feedback loops are the constituents of the metabolism of existing socio-technical systems ([11]) made by humans, machines, organisms, and the natural environment in which they are immersed. Rather than by their energy and material content, the metabolism of socio-technical systems is, however, given by the amount of energy and matter that is processed per unit of

([9]) Genetic profiles and other profiles nowadays largely employed for statistical analyses as well as traffic and energy maps, geo-satellite images generated for various reasons, and plenty of other kind of maps that can be continuously generated through these technologies represent examples of these snapshots.

([10]) This report section will focus in particular on the notion of societal and ecosystem metabolism and on its multi-scale integrated analysis as described e.g., Giampietro et al. (2009), and Polimeni et al. (2009).

([11]) For an historical overview of the concept of socio-technical system, see Emery and Trist (1960). It might be worth highlighting that, in so far as it takes energy, matter and information flows as socio-technical systems constituents, the socio-technical perspective presented here differs from the one presented under A sociotechnical perspective and generally adopted in this report. The latter perspective relies indeed on a flat ontology whereby also energy, matter and information flows are seen as the outcome of a social construction and political negotiations (for further information on flat ontology see, e.g., Latour (2015). To not lose track of this important difference, systems discussed in this section have been named socio-technical, whilst the perspective presented under A sociotechnical perspective has been named sociotechnical (without dash).

time within given transformation processes. As discussed in the following paragraphs, the study of the rates at which energy is produced and dissipated within socio-technical systems provide very interesting insights into how production and consumption activities are interconnected.

As any living organism whose survival relies on specific rates of energy intakes and expenditure, socio-technical systems, either seen as aggregates of persons, households, cities, or countries within given technological and natural environments, must rely on specific energy inputs and energy dissipation rates. In socio-technical systems, energy and matter flow can persist only thanks to a balance that has to be guaranteed between given energy input rates and energy consumption and dissipation rates. Whenever these structures change, these rates also generally change and vice versa. The energy metabolism of socio-technical systems can then, in principle, be measured by adopting a very particular definition of power capacity that considers the amount of personal time spent by people to accomplish a given task. More specifically, this power capacity can be calculated as the ratio between the amount of exosomatic energy used by persons accomplishing a given (technologically mediated) task over the amount of personal time spent for this accomplishment ([12]). This definition of power capacity is particularly relevant because it connects a critical parameter used to assess human activities (i.e., the amount of consumed personal time) to the energy consumed by machines, so linking together a variable used to assess a social aspect with a variable measuring a technological aspect (i.e., the energy consumed or generated while accomplishing a given task).

When applied to households, this definition can serve to characterise the power capacities of all practices reproduced within households during daily activities. It can be used, e.g., to measure the power capacity of existing practices linked to washing clothes, preparing and eating food, and so on. In the case of practices related to washing clothes, the associated power capacity can, e.g., be calculated by the ratio between the final energy consumed by a washing machine during a washing cycle and the personal time spent to prepare and activate the washing machine. For practices linked to food preparation, the associated power capacity can be, e.g., estimated by the ratio of the final energy consumed by an oven to cook a given food over the personal time needed to prepare the food and activate the oven ([13]). By monitoring how this quantity changes over long time-spans, it is generally possible to conclude that the historical evolution of practices is very often characterized by an increase in the associated power capacity. This is typically due to an ever-increasing need to save time and delegate to machines the activities accomplished for the reproduction of social practices. Delegation leads to a reduction of the personal time to be spent for practices reproduction and, therefore, to an increase of the associated power capacity.

This proposed definition of power capacity can be generally used to measure the energy metabolism of any socio-technical system (e.g., a person, a given practice reproduced by a person, a household, a city, a country, etc.). Whatever the system, its energy metabolism always consists of a power input that is partially transformed into useful energy consumed per unit of time and is partially dissipated in the surrounding environment. When applied, e.g., to a city, this notion may serve to identify its underlying energy structure. Like any organism, a city is indeed kept alive by specific energy input rates and associated energy consumption and dissipation rates. Energy is consumed and dissipated at given paces in a city depending on factors like the number of total personal hours dedicated by households to leisure, chores, commuting, etc., and on the final energy consumed by technologies used while performing these activities. Nevertheless, the energy input rates to a city must be commensurate to the rates of consumption and dissipation. Input rates depend, in turn, on the total amount of personal hours spent by citizens for energy production and on the amount of energy that can be generated per unit of personal time consumed from the specific energy resources used ([14]). There is a balance between energy inputs, consumption and dissipation rates that must always be maintained by using given amounts of total personal time at the city level while consuming or producing involved energy amounts. Whenever consumption and dissipation rates change in a city, input rates must be changed accordingly and vice versa. Reasons for a change in consumption and dissipation rates at the city level depend on a variation in the total personal time

([12]) As already mentioned, report authors are here referring to the definition of energy metabolism that has already been adopted and proposed e.g., in Giampietro et al. (2009), and Polimeni et al. (2009). Exosomatic energy denotes energy conversions outside human body which are still operated under human control.

([13]) These definitions of power capacity are clearly very rough. The energy spent to reproduce the practices mentioned is not just given by the energy consumed by the appliances mentioned. This energy should, e.g., include also the metabolic energy spent by persons involved and by additional appliances possibly used (e.g., in case of food preparation practices, the energy spent by the boiler heating the water possibly used to prepare the food should also be considered). Moreover, the personal time spent to reproduce the practices mentioned should also include, e.g., the personal time spent for the maintenance of the appliances.

([14]) By following Polimeni et al. (2009), it can be roughly assumed that all the personal time spent at work by people contribute either directly or indirectly to the generation of the energy input to the city (either this work is accomplished in the tertiary, or in the industry or in the agriculture sectors).

used to consume and dissipate energy or on a variation in the amount of total energy consumed and dissipated per unit of time by its citizens ([15]). Variations in the total personal time spent to consume may be due to, e.g., increased delegation to machines for the reproduction of given practices, a variation in the age structure in households causing a change in the overall time available for consumption and dissipation ([16]), a change in the number of unemployed people, or even to a change in the share of the male and female population. Variations in the total energy consumed by citizens may depend in their turn on a variation in the energy efficiency of technologies used by households, on a variation in the age structures within households, on the installation of additional energy end-use technologies, etc. ([17]). Although most of the factors that can affect the energy consumption rates of a city can also alter the energy input rates, the latter can change for additional reasons, including, e.g., a change in the energy sources used ([18]), a change in the relative distribution of people working in the different economy sectors directly or indirectly linked to energy production, a change in the amount of energy inputs made available to the energy system, a change in the efficiency of the energy production system, a change in the production volumes, etc. When studied from a metabolic point of view, activities carried within a socio-technical system have to comply with overall energy conservation principles, which establish that the amount of energy dissipated per unit of "personal" time cannot exceed the amount of energy intake over the same unit of time. This balance has to be achieved at any level, from the level of a single person to the level of his household, city, nation, etc.

The few considerations so far illustrated concerning the energy metabolism of socio-technical systems should suffice, e.g., to grasp the huge impacts on energy systems organization caused by a massive shift towards renewable energy sources for the provision of the energy inputs needed by these systems. When taking place at the city or the country level, a shift to renewable energy sources and the consequent changes in the rates at which final energy can be supplied can entail a radical reorganization of the activities in all sectors of the economy. There are then two relevant phenomenological principles ([19]) generally reflected in the evolutions of metabolism of complex socio-technical systems. These two principles are particularly relevant to get insights into the impacts of these evolutions on energy sustainability, including the case of a radical shift to renewables relying on energy prosumers.

Minimum entropy production or minimization of the input needed to obtain a given output are the expressions frequently used to refer to the first principle, which dominates in a situation of energy scarcity and stable system boundary conditions. This phenomenological principle has been formalized by Prigogine (1961), Glansdorff and Prigogine (1971), Nicolis and Prigogine (1977) for energy-dissipating systems in a steady non-equilibrium state and applies to systems that are close to the thermodynamic equilibrium. Broadly speaking, this principle implies that, in a condition of energy supply limitation and quite stable boundary conditions, system structures and components requiring lower energy input to produce a given output have a competitive advantage and will prevail over less efficient ones (i.e., over system structures requiring more energy to produce the same output), determining a system reorganisation that can be characterized in terms of increased overall efficiency. This reorganisation causes, therefore, a lowering in the diversity of options available to perform the same function in the short term, and may put the system survival at risk, in case of a change in the boundary conditions. On the other hand, it diminishes the stress on the environment that supplies energy and contributes

([15]) As already mentioned, it can be assumed that activities performed by people while at home are related to energy consumption and dissipation, whereas activities performed while at work are directly or indirectly linked to energy production. If energy rates are calculated on a daily basis, the total amount of personal time spent in energy consumption and dissipation in a city can be estimated based on the age structure in the households of this city by multiplying the number of citizens falling under each age range by the average daily time spent at home by these citizens, this average daily time clearly depending on the age range considered. The total amount of daily personal time dedicated to generating energy input can instead be assumed to equal the time spent at work under each age range, this time corresponding approximately to 24 hours minus the time spent at home. For further information on how to perform these estimates, see Polimeni et al. (2009). Clearly, these estimates of the daily personal time used for energy consumption and dissipation are very rough. The personal time used for energy consumption should for example include also the amount of time spent for traveling for leisure activities, whereas hours spent at home during teleworking should be considered as hours spent for activities related to energy production.

([16]) It is, e.g., generally observed that the oldest and the youngest people in households spend a larger part of their daily personal time in energy consumption compared to middle age people in households who usually have an employment and are hence involved also in activities related to energy production. Whenever the age structure within households' changes, also the average personal time used by persons to consume is supposed to change (Palm, 2017).

([17]) Although implicitly mentioned in the previous paragraphs, it may be worth highlighting that the energy metabolism of a city is the ratio between the total amount of energy consumed or produced and the total amount of personal hours spent in energy consumption or production by citizens.

([18]) Notice that, as mentioned in previous paragraphs, renewable energy sources can typically generate lower energy input rates compared to non-renewable energy sources.

([19]) These principles are phenomenological because they are observed within socio-technical systems but cannot be deducted from existing physical laws.

to liberating energy that could be used to create new structures whereby further situations of energy scarcity, possibly happening in the long run, could be faced.

The second principle has been formalized in terms of maximization of energy flows and was proposed for the first time by Lotka (1922). Several names have been proposed for this principle by different scholars. It has been defined, e.g., as 'maximum power principle' by Odum and Pinkerton (1955), as 'maximum exergy degradation' by Morowitz (1979), Jørgensen (1992), Schneider and Kay (1994). It establishes that in a situation of energy abundance and time scarcity, complex systems tend to increase the speed of energy intake in order to speed up the activity of existing structures and generate new structures. This enhanced diversity and intensification of the activities performed take place at the expense of system efficiency. The overall effect of the augmented energy intake is hence described in terms of system growth and increased system power capacity accompanied by a decrease in system efficiency. The higher system power capacity may determine higher stress on the environment and on the boundary conditions. On the other hand, the higher diversity achieved increases the possibility of a system reorganisation in case significant systems boundary conditions change. System maximum power capacity corresponds to a status of higher diversity which is indeed a prerequisite for higher system adaptability. This status enhances the chances of system survival whenever the conditions of energy resources scarcity and minimum entropy production are possibly achieved.

These two principles indicate how complex systems evolution can be driven by a tendency to increase power capacity, whilst increased systems efficiency can be functional to liberate energy used for further power growth and for better system integration into the environment. Complex systems tend indeed to augment their energy metabolism and the diversity of their outputs. Their reorganization and energy saved at a given scale during a phase of energy scarcity generally serve to allow maintaining this trend. It should not be difficult to realize how this trend can also be generated in the case of future renewable energy and highly interconnected networks where energy prosumers are supposed to operate (see, e.g., Labanca et al., 2015). This trend might be generated either because:

1. Energy end-use efficient technologies are installed at network nodes, and the energy not used thanks to these technologies is made available to other nodes;
2. Energy/electricity prosumers at the nodes of these networks are highly incentivised to augment the amounts of energy produced in order to sell it to the network and to make this energy available to other prosumers connected to the network;
3. The possibility to generate energy may represent an additional push to increase power capacity by installing additional end-use technologies.

Altogether, these factors can lead to an increased power capacity of the energy network, whose impacts on energy sustainability of the overall energy systems have so far been scarcely studied, despite their relevance.

3 Prosumerism, Renewable Energies and Domestic Energy Use

In the energy field, much research has been done on both the consumption side and the production side of the energy equation. The aim is not to summarise all that work here but rather highlight some aspects connected to renewable energy technologies and domestic energy use that are considered relevant for this study of energy prosumerism. The idea of the 'energy prosumer' started emerging in the early 2000s and has become subject to a large amount of both research and political ambitions. The idea of energy prosumerism appears to be attractive particularly due to an increase in microgeneration technologies of renewable energy combined with an increasing interest in smart, domestic technologies (e.g., Juntunen, 2014; Olkkonen et al., 2016). The typical energy prosumer has photovoltaic (PV) panels on the rooftop of a house as well as smart metres and home energy management systems. Parag and Sovacool (2016, p. 1) define energy prosuming as 'when energy customers actively manage their own consumption and production of energy'. In this understanding, energy can both relate to electricity and heat, although it is most common to focus on electricity, and the various implications that more active energy management will have for consumers. The way in which households, previously seen as merely end-users, users or consumers, are actively engaging with their own production of electricity (or heat) is the main reason why the prosumer term is preferred – also given the potential they have in transforming the existing energy system (Juntunen, 2014). Therefore, a common definition is the one employed by Bremdal (2011, p. 3): 'A prosumer is a consumer that becomes resonant with the energy market through systematic actions and reactions that aim to increase personal or collective benefits'. It is particularly interesting that the word "resonance" is used here, as, since Marx, the critique has been the worry of alienation of workers that do not own their means of production: can energy prosumers lead to a more resonant relationship with energy?

Energy prosumerism could mean having PV panels on the rooftop of a house, a small wind turbine on the property, but it could also mean producing own heat, e.g., through chopping, stacking and burning firewood. Burning wood would be considered a classic form of prosumer activity since the person both produces and consumes the energy. It would create a direct form of use value, although it implies taking over large parts of the value chain of production. For many, such a change is inconvenient, which in turn impacts the use value.

In other words, what some would think of as an insurmountable or even unnecessary task, others would embrace as a desirable past-time activity. That means that what can be considered use value depends on the case and context in question. Such aspects make the prosumer term more complex when talking about electricity or heating, as it impacts a wide range of issues relating to everyday life, inclusion, and justice, such as age, class, and gender (Standal et al., 2020). Prosumer activities impact daily routines and activities and may deepen, reinforce or challenge already existing patterns of social division and domestic work depending on how the prosumer is conceptualised and implemented. These topics will be revisited in Prosumers and domestic energy use.

Electricity prosumerism can also include forms of heating since heating is becoming more and more electrified in the shape of heat pumps and similar technologies. Overall, the prosumer concept can be connected to 'renewable electricity production and consumption close to its point of generation (solar PV, small scale wind and hydro power), low carbon heating systems (heat pumps, heat networks, and biomass) as well as vehicle electrification and storage' (Brown et al., 2020, p. 1). Since electricity is multipurpose, there is not necessarily a direct connection between how it is used and how it is produced. This makes it difficult to single out the effects of prosumption *per se*. Compared with heating with logs, for example, taking over parts of the value chain may not require as much recurring effort since a PV panel is installed once with a 20-year lifetime, whilst chopping, stacking and drying wood must be done repeatedly. What is more, everyday life set-ups are composed by various practices and their dependence on electricity may vary: e.g., writing on a computer may be replaced (temporarily) by a notebook and a pen, light can be provided (temporarily) by the sun/fire, and some practices cannot be carried out at all without electricity, e.g., any ICT-related practice. As pointed out by Jalas et al. (2016, p. 18), 'all infrastructures, and particularly infrastructures that are plagued with failures and interruptions, co-exist with alternative systems of provision and a related alternative patterning of time'. In other words, use values are relative and situated, and depend on substitution, which makes the link with how they were produced difficult to observe.

This chapter reviews two types of literature to understand better the producer and consumer sides regarding renewable energy and smart energy technology constellations, typically associated with prosumerism. These two are sociotechnical ([20]) configurations of renewable energy technologies and domestic energy use.

([20]) To be noted that the authors refer to the social constructivist notion, and not the more systems-oriented understanding presented in 2.3 and 2.4. For more on this, see footnote 11 and, more in depth, Sovacool and Hess (2017).

3.1 Sociotechnical configurations of renewable energy generation

Social studies of renewable energy technologies have a long history of research that has been burgeoning for the past 10-15 years. Much of the research has been grappling with the effects of renewable energy technologies on public participation and engagement, on so-called 'acceptance' of these technologies, and on the effects of user-led innovation towards more sustainable societies (e.g., Ornetzeder & Rohracher, 2006). Walker and Cass (2007, 2011) provided a first conceptualisation of what they term sociotechnical configurations of renewable energy. This is done through an integrated analysis of the technical, social and participatory ('public') aspects of these renewable energy technologies. In terms of the technical aspects, one can imagine a wide variety of renewable energy technologies. Juntunen (2014, p. 20) provides a useful overview of different small-scale micro-generation technologies, as can be seen in Table 1. Overview of a variety of small-scale micro-generation technologies.

Table 1. Overview of a variety of small-scale micro-generation technologies.

Energy Source	Energy Technology	Output Power Type
Hydro power	Small hydro-turbines	Electricity
Wind	Micro-wind power	Electricity
Solar	Solar PV	Electricity
Solar	Solar thermal collector	Heat (water)
Solar	Solar air collector	Heat (air)
Biomass: Wood	Fireplaces	Heat (air or water)
Biomass: Wood	Wood burning boiler	Heat (water)
Biomass: Wood pellet	Wood pellet boiler	Heat (water)
Outdoor air heat (+electricity)	Air-source heat pump	Heat (air)
Outdoor air heat (+electricity)	Air to Water heat pump	Heat (water)
Various sources (e.g., bio-gas, wood, wood pellet)	Micro-CH P/Stirling Engine	Heat and electricity
Hydrogen (from renewable sources)	Micro-CHP/Fuel Cell	Heat and electricity

Source: Juntunen, 2014, p. 20.

To define the social aspects, Walker and Cass (2007, p. 460) list four categories of questions that explain better the meaning and purpose of the technologies in questions. These four are:

> ***Function and service***: *what is the generated energy being used for in terms of the services (comfort, warmth, visibility, mobility etc.) that it is providing? Who utilises these potential services and what physical and institutional distance is there between the point of energy production and the point of service "consumption"?*
>
> ***Ownership and return***: *who owns the technology and how is this ownership organised – privately, publicly, collectively – and at what scale – locally, nationally, internationally? What benefits, monetary or otherwise, are returned as a consequence of ownership?*

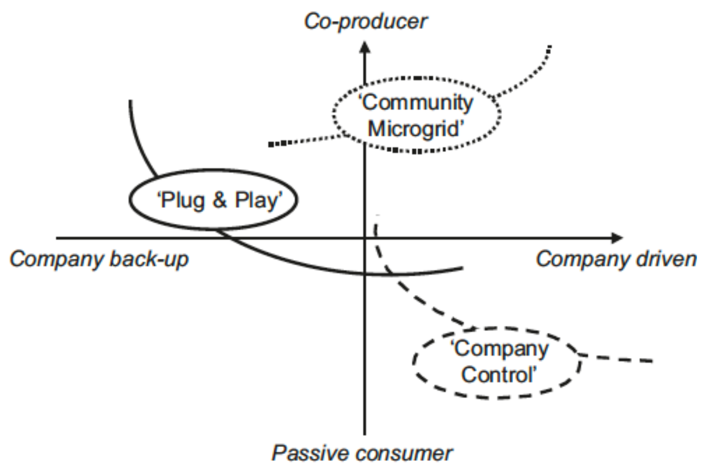
> ***Management and operation**: who manages, controls and maintains the hardware and how is this organised – privately, publicly, collectively; locally, remotely? To what extent is management regulated and through what principles and mechanisms?*
>
> ***Infrastructure and networking**: is the energy that is generated fed into an electricity or heat network (is it on or off grid?) and if so, what scale of network – local, regional or national? What/who does this network supply and how is it managed (locally, distantly; publicly or by regulated market?).*

They point out that renewable energy technologies are highly variegated and cannot really be understood as one common concept in terms of implementation into society. Depending entirely on what type of technology one is talking about, whether it is an offshore wind turbine, a small-scale wood-chip burner or a solar PV panel, one will observe different social arrangements and forms of public participation and engagement. Each technology also operates at different scales, from macro, through meso, micro and pico scales, which will likely also generate different forms of publics and levels of engagement. What is more, some technologies were found to be more scalable than others. Micro-wind is not as useful or even possible to use in an urban setting, but solar panels are more scalable and can be used at any scale.

This conceptualisation is useful, because it shows that when talking about 'prosumer' arrangements, one cannot generalise. The effects such arrangements will have on both energy use and reconfigurations of production and consumption will depend entirely on the three aspects delineated by Walker and Cass (2007): technical, social and the publics in question. These can be arranged in different ways, and it is not only the technologies that can change but the management, the operation, the business models and the various stakeholders and actors that are involved in the project. The form of prosumerism that we talk about here has been studied under different headlines: microgeneration, decentralised energy technologies, co-provision, co-creation and co-production are some examples. They have been studied with a variety of ambitions: to understand how the renewable energy technologies are domesticated (Juntunen, 2014), how they relate to the electricity grid as co-providers (van Vliet, 2006), how renewable energy co-providers should be understood differently in terms of public acceptance (Sauter & Watson, 2007), how they can lead to certain forms of energy citizenship (Devine-Wright, 2007a).

Sauter and Watson (2007, p. 2 774) showed an early idea of the difference between co-provision and passive consumers, seen in relation to technology ownership (see Figure 3): if the technologies were owned by private households (with "back-up", i.e., sending the electricity to the grid), or by companies where the aim would be to 'use fleets of micro-generators as a substitute for central power generation—i.e., as a virtual power plant' (p. 2 774).

Figure 3. Sauter and Watson's deployment models for micro-generation technologies.



Source: Sauter and Watson (2007, p. 2 774).

The concern that Sauter and Watson (2007) had was that these different types of user-groups would require different strategies with respect to implementation and acceptance of these technologies. They find that, compared to traditional electricity systems, these new micro-generation technologies would 'need more "active" social acceptance' (p. 2 777). Walker and Cass (2011) provide an extension to this and find five different modes of implementing renewable energy projects in the UK. These five are the public utility, private supplier, community, household, and the organisational.

Since 2007, the academic debate has moved from an understanding of how different social groups can "accept" these new technologies, through an idea of 'energy citizenship' (Devine-Wright, 2007a), to how they can be engaged, co-produce and participate in shaping new material arrangements that are of interest to them (e.g., Ryghaug et al., 2018). Walker and Cass (2011, p. 50), for instance, point out that publics are not one homogenous mass. Instead, they can be thought of as 'imagined, inscripted and produced through various practices, such as when designing, deploying and debating about technologies'. Much of the work done by social scientists has centred on gaining a more nuanced understanding of what is typically only referred to as "the public", which often has been simplified by government and business actors. For instance, the concept of "Not In My Backyard" (NIMBY) has been critiqued to be a gross simplification of the responses from those that have been implicated in energy infrastructure developments (Devine-Wright, 2009). The position was perhaps formulated most stringently by Wolsink (2007, p. 2 692), who found that

> *Local opposition cannot be explained by the egotistical motives of local residents. When the inclination to behave according to (supposed) backyard motives is investigated, the scale to measure this phenomenon appears to indicate commitment to equity issues and fairness of decision-making.*

The ways in which "the public" is imagined by companies and governments has implications for the types of participatory procedures that are chosen in each case (Walker et al., 2010). Walker et al. (2010) found that the public typically was perceived through NIMBYism, or with a hostile attitude towards the renewable energy project in question, which affected the project by extension, for instance, through siting decisions. That was, for instance, illustrated by a study of wind power project siting in Sweden, finding 'a higher likelihood of rejection [of wind turbines] in areas with more highly educated people and people working in the private sector, compared to a higher likelihood of approval in areas with more unemployed people' (Liljenfeldt & Pettersson, 2017, p. 648). In summary, when thinking about participation and the public, a more nuanced understanding can make it easier to see that people can be engaged in a variety of forms, and that acts of prosumerism are much more than just a type of mindset or opinion. It is embedded in infrastructures, political decisions, as well as everyday practices and habits.

Work on energy prosumers since around 2015 has provided more analytical depth, as it has been based on a larger number of empirical cases and types of business models. Today, energy prosumerism is no longer a marginal phenomenon, and more than 2 500 energy cooperatives exist in Europe, in addition to other forms of energy prosumers (Wittmayer et al., 2021). Winther et al. (2018) study prosumers in Norway and find that there are three main paths to becoming solar PV prosumers: the eco-villager path, the 'smart home' owners path, and the individual prosumers path. In line with findings from other countries, they find that these prosumers altered their consumption: 'By becoming prosumers, most households started to use certain appliances at different times during the day, running appliances when the sun was shining' (Winther et al., 2018, p. 91). Nevertheless, none of them reduced their electricity consumption (but the consumption also did not increase). The main finding that was relevant across the three groups was that being a prosumer with solar PV on the roof was associated with signalling an identity with tendencies to environmentalism, comfort and desire for new technology (see more on the "resource man" in Prosumers and domestic energy use). In other words, the signalling effect of becoming a prosumer was central.

Inderberg et al. (2018), who also limit prosumerism to be mainly about solar PV, compared Germany, Norway and the UK, and found that there are similarities between the countries, but also differences. The similarities were that all three started with smaller-scale pilot schemes that helped with the bureaucratic hurdles, then came a phase where third-party installers were speeding up installations of domestic solar PV. The differences were that both German and UK prosumers were driven by the need to decarbonize the electricity grid, but this was not the case in Norway. In a more recent study, Inderberg et al. (2020) looked more closely at Norway and found that prosumers there were motivated by the same aspects as identified by Winther et al. (2018), and that increased economic support from the government could increase the uptake of Norwegian prosumers. It is somewhat unclear why these two studies use the term "prosumer", given that they actually study the proliferation of small-scale solar PV installations with the possibility to use the power themselves or sell electricity back to the grid. These are naturally very interesting observations, but as this report aims to show, much more can be said on energy prosumers than on renewable energy micro-generation.

Stikvoort et al. (2020) investigated the difference between 'solar prosumers' and regular electricity consumers with respect to environmental behaviour. They found that prosumers were more compelled by pro-environmental behaviour than consumers: 'prosumers had higher confidence that pro-environmental behaviours would benefit the environment, improve their comfort and life-quality, they felt more moral responsibility to perform such behaviours and assessed their electricity awareness as higher' (Stikvoort et al., 2020, p. 2). Juntunen and Hyssalo (2015) conducted a review of sociotechnical configuration of microgeneration technologies in the 21st century and found that the 'potential for new configurations can be found particularly in heat producing micro-generation with solar heat, heat pumps, and biomass.' As renewable microproduction technologies spread out more, one could also expect that a larger number of so-called "user innovations" would occur. Hyysalo et al. (2017) study this using a wider understanding of prosumerism (incl. solar, pellet and heat-pumps) and find that such innovations indeed do happen, but that they are not yet very widespread. Nevertheless, they conclude that it would be a mistake to exclude such micro-scale innovations in the future of renewable energy prosumerism solutions.

3.1.1 Energy decentralisation

The idea of energy decentralisation is central to energy prosumerism and deserves special attention. Distributed energy projects can be defined in a variety of ways. In general, they are small with installation sizing between kilowatt and megawatt levels, they are close to the electricity demand, the energy generated is mainly for local consumption accessed at the local distribution network, and, typically, the project includes technologies for both sides of supply and demand, such as smart metres. Nevertheless, the electricity can also be "off-grid" or "mini-grid", implying that it is not sent to the main electricity grid. Instead, it is used locally, either directly in a household or in a local mini-grid. The prosumerism trend is not only requiring a higher degree of flexibility for power grid managers but also pointing towards decentralisation of energy generation, with potential repercussions for traditional energy supply actors.

Berka and Dreyfus (2021) provide some fascinating insights into this through a special issue with the international comparison of institutional frameworks that enable or constrain prosumerism. They find that energy decentralisation generally is referred to in three different dimensions: 'first, as a shift in technological infrastructure, second, as a process that creates opportunities for new stakeholders within the market context, and third, as a normative goal in itself, associated to values such as citizenship, justice and democracy.' (p. 2). Energy decentralization is defined by them as 'a process by which decision-making and participation in the production, consumption, trade, planning and regulation of energy is to some extent distributed away from a central authority towards the final consumer.' (p. 2). This definition puts the idea of participation centrally, implying that the "final consumer" will have higher degrees of participation if energy is decentralized. One aspect of their findings is related to decarbonization: it is not necessarily always evident that a decentralized energy solution is leading more quickly to decarbonization than a centralized one, and in this case, actors may prefer centralized solutions such as hydro power or nuclear energy. Other concerns highlighted relate to costs: if centralized electricity provision would be cheaper, associations of consumers might prefer these to more decentralized solutions. These different stances for and against decentralized energy are summarized in Table 2.

Table 2. Berka and Dreyfus' overview of views on decentralized energy.

Understanding how different assumptions, knowledge, attitudes, and worldviews shape distinct views on including decentralised energy.

	Proponents	Opponents
Theory of change	Emphasis on social, cultural-behavioural change and public buy-in	Emphasis on supply-side technological change
Scope of analysis	Emphasis on potential advantages of functional integration heat/power generation, DSM, appliances, EV's at the consumer level	Emphasis on costs of single technologies at the consumer level
Criteria used to justify projects	Financial viability, social, local economic impacts/co-benefits, equal access, social justice	Least cost to the overall economy (opportunity cost)

	Proponents	Opponents
Trust in institutions and incumbents to deliver the energy transition	Low	High
Risk appetite	High	Low

Source: Berka and Dreyfus 2021, p. 4.

Much popular discussion has centred around how such an energy decentralization should be organised. In this discussion, the role of blockchain technology is frequently featured. Ahl et al. (2020) studied the role of blockchain technologies in a Japanese energy system and found both challenges and opportunities to the usage of blockchain. These were relating to technology, economy, society, environment and institutions. Their conclusions are optimistic, and they point out that if the barriers can be overcome, then blockchain in the energy sector 'may contribute to digitalization, decentralization and decarbonization in the future' (Ahl et al., 2020, p. 8). In a study of blockchain technologies from the Netherlands, Buth et al. (2019) found that 'the impact of blockchain does not seem to be as disruptive and decentralizing as may be expected' (p. 194), and that the introduction of this technology potentially could lead to some new challenges such as 'centralization of power around blockchain operator' (p. 203). We will get back to the role of blockchain in Technological innovations and energy communities – from giants to ant-like networks, which looks at community energy more in detail. In general, the findings from Berka and Dreyfus (2021) special issue is that energy incumbents have a large influence on the speed at which decentralization happens across the different institutional and regional contexts studied: 'there is a need to acknowledge that regime actors have privileged positions that they use to actively and passively shape the form and extent of decentralization takes place, who participates and who benefits' (p. 4). This implies that close scrutiny of the various forms of institutional and practical impacts that incumbent energy companies and institutions have is necessary to ensure inclusive institutional dynamics that ensure fair participation.

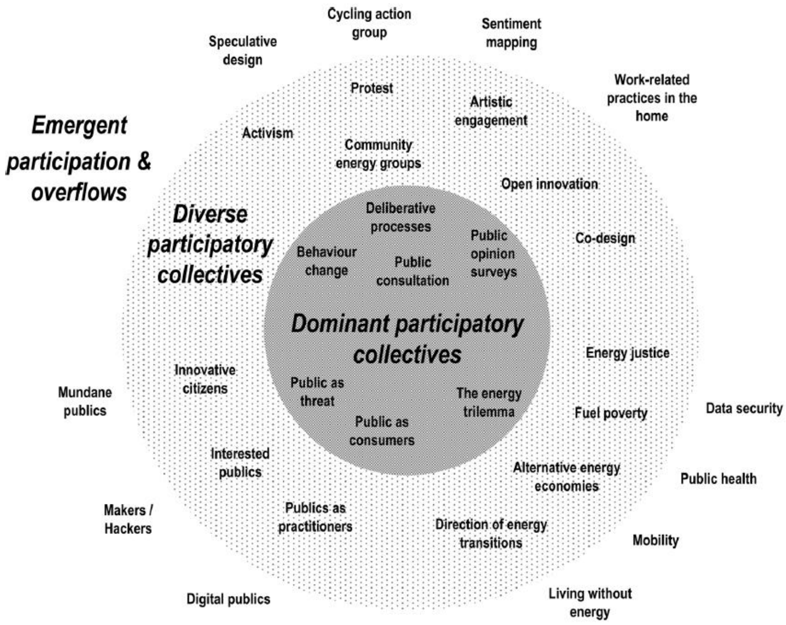
3.1.2 Prosumers and level of engagement with renewable energy technologies

Depending on how we understand who the users are and how they are able to participate, we will be able to say something about the levels of engagement with renewable energy technologies. One useful way of thinking about participation is that it is co-produced in socio-material collectives (Chilvers & Longhurst, 2016). That implies moving beyond a pre-given understanding of what participation and engagement are. Instead, a wide variety of types of participation can be imagined. For instance, Chilvers et al. (2018) identify 30 different types of participation in energy transitions in the UK (see Figure 4. Forms of energy transition participation.). These vary from dominant participation practices that are well established and more central to the energy system, such as public opinion surveys and deliberative processes, to more decentralized and emergent participation practices, such as speculative design, cycling action groups, or even living without energy. In between these two categories, they identified "diverse participation practices" such as artistic engagement, co-design, community energy groups or activism. Chilvers et al. (2018) point out that in the UK, the more centralised methods are considered more legitimate, which can discourage other forms of participation. Thus, relying on 'specific pregiven meanings, forms, and qualities of participation' can cause confusion and hamper participation by overly simplifying the multiple varieties of contemporary public engagement that exist (Chilvers & Kearnes 2020, p. 349).

Wittmayer et al. (2021) also have a very useful delineation of the various actors involved in the mainstreaming of prosumers. They first identify that mainstreaming occurs through three main logics: the market (i.e., commodification), the state (i.e., standardisation, formalisation), and the community (i.e., socialisation). As seen in Figure 5, Wittmayer et al. (2021, p. 4) define a hybrid set of negotiations that are ongoing in developments of prosumerism activities, implying that they move beyond a simplistic, binary understanding of prosumers vs incumbent energy providers. In reality, the picture is much more complex, which means that in order to understand how prosumerism activities can be promoted and lead to more just and inclusive forms of participation, we must not oversimplify the defining lines of dissent. Following the three logics described, Wittmayer et al. (2021, p. 8) found that

*The current energy system allows everybody to benefit from secure and reliable energy supply, but only a small group from the **financial** benefits while the ecological costs are overlooked. From discussing gaining recognition for energy activities, we find that it is important to understand the extent to which **formalisation** is necessary and desirable since informality might lower the barrier for involvement and increase creativity. Finally, from discussing the delineation of access to energy activities and resources, we derive that the **public** logic can serve to regulate market logic but also community logic to allow for processes and benefits of prosumerism to be open for and belonging to all – rather than serving the interest of certain social groups.*

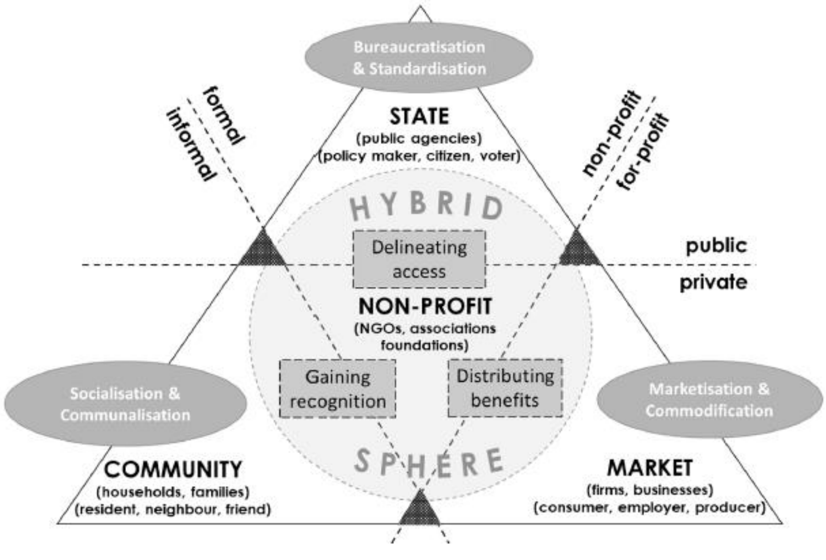
Figure 4. Forms of energy transition participation.



Source: Chilvers et al., 2018, p. 205.

Some of the consequences of these findings for policymaking are detected to be about recognizing that informality can be a resource in terms of implementation, which for instance, can be of use when looking at prosumerism at the community level. This topic will be delved more deeply into in Chapter 4.

Figure 5. Types of actors and hybrid forms of engagement.



Source: Wittmayer et al., 2021, p. 4.

3.2 Prosumers and domestic energy use

In a PhD dissertation on prosumers, Fox (2017) concludes that the prosumer project potentially can transform into new spheres that involve what is called "Energy Shifting-Storing-Saving & Sharing" (E4S). It is within this field that a large potential of prosumerism is held, which also might lead these types of technological arrangement to be more accessible for a wider range of people. Fox (2017) observed several potentially ground-breaking changes following from moving towards E4S. Prosuming moved from a project mainly for the affluent and individual, to

> *One that many practitioners felt should have a collective outlook - sharing knowledge within their community - and an aspiration for sharing energy. This in turn imbued the project with the importance of frugality and 'mottainai' - a respect for resources. It was also transformed from a project focused on shifting energy to sunny days, to one that could be performed all year round. (pp. 184-185)*

This section, therefore, looks closer at the domestic consumption end of the prosumerism project. There is a burgeoning amount of social science research with a sociotechnical lens done within this field, and we touch upon some core aspects relating to prosumerism and domestic energy use.

Ellsworth-Krebs and Reid (2016, p. 1 993) define energy prosumerism as 'when a household is simultaneously a producer and consumer of their heat and/or electricity via microgeneration' and point out that 'the concept of prosumption offers great potential as a device to reveal the complexity of energy production and consumption relations' (p. 1 990). This is so because energy prosumerism has 'potential to create new patterns of demand through changing a product's use value' (p. 1 992). In other words, changes in use value can occur if consumers become prosumers. The idea is that the occurrence of a (renewable energy) microgeneration technology, i.e., a solar PV panel on a roof or a wind turbine in the garden, might alter the way we use electricity. This idea is sometimes also referred to as the 'double dividend', as it can offer benefits to both individuals and society:

> *The total benefit of domestic photovoltaics comes not just from displacing fossil fuel generation, but because of its location within the home, there is a potential influence on energy consumption behaviour (e.g., load shifting, conservation, and changing purchase behaviour). Thus, a positive behavioural response, leading to further energy conservation providing a "double-dividend" for climate change. (Keirstead, 2005, p. 1 249)*

One aspect of this change in electricity provision is that it might make it less obvious that electricity will always be there: it is there mainly when the sun shines or the wind blows. We might imagine a future society that has reached 100% renewable energy, in which the intermittency of electricity generation to a larger extent will decide consumption patterns. This could mean that the understanding of power as something that always 'is there' would be challenged. Intermittency implies that when there is no production, we no longer can consume, showing the close interrelation between production and consumption. Such topics are, to date, relatively understudied, and more research should be directed at understanding the introduction of microgeneration technologies and the implications for everyday life (Ellsworth-Krebs & Reid, 2016).

There is a need for critically examining the co-production at play when technologies and people bond. On the one hand, smart grid demonstration pilots generally aim to show how smart energy technologies can be a solution to the presumed lack of consumer rationality exhibited in the energy market (Throndsen, 2017). Social science and humanities research on people who live in smart homes, on the other hand, tend to focus on the broader implications of smart energy (or smart home) technologies for how we organise our everyday lives and society (Hargreaves et al., 2018). Such research seeks to ask more fundamental questions about the 'smartness' of these new technologies (e.g., Wilhite & Diamond, 2017), whether there is evidence that smart technologies generate energy savings (e.g., Nicholls et al., 2020), or question the social value of ever-larger quantities of metering data (Kragh-Furbo & Walker, 2018).

A wide range of arguments construct and hold in place the idea of 'smartness': resource, energy and time efficiency are prominent examples, as are ideas of security (e.g., Gram-Hanssen & Darby, 2018), health benefits (e.g., Wilson et al., 2015), comfort and independence (e.g., Nicholls et al., 2020). Research from the social sciences and humanities has in recent years critiqued various aspects of the introduction of smart energy technologies. Visions and expectations about smart living are often based on understandings where people will accept, adapt, extend or even co-create new technological systems in their everyday lives. Within this range of expectations, people and the role of households are typically thought of in two different ways: on the one hand, they are thought to be passive and need not do anything new or differently because of new automation possibilities (Strengers, 2013). On the other hand, end-users are thought to be informed, empowered and actively engaged as co-creators of future solutions (Prahalad & Ramaswamy, 2004). Living in smart and energy-efficient homes can be both time-consuming and demanding, and instead of energy saving, may end up generating energy intensification through new forms of energy demand (Hargreaves et al., 2018). Korsnes et al. (2018), who studied different cohorts of groups (students, families and elderly) living inside a high-tech zero-emission building, found that the technologies within the house had some impacts on the groups, but their relationship to energy use appeared unchanged. However, for the elderly groups, it was observed that the ways in which the house was heated impacted existing habits of heating with firewood. This, in turn, impacted 'the way in which the different technologies were seen as useful in their everyday life' (Korsnes et al., 2018, p. 232), implying that the technological arrangements seen in smart homes must be adapted to users in question.

One frequently reappearing persona discovered when doing research on domestic energy use is the "resource man" (e.g., Throndsen & Ryghaug, 2015). This man was first described by Strengers (2013) and was defined as representing the 'energy industry's "resource bias" projected onto energy consumers. In his ultimate imagined state, Resource Man is interested in his own energy data, understands it, and wants to use it to change the way he uses energy.' (Strengers, 2014, p. 26). The point was that the energy utilities and power companies often have a particular person in mind when designing smart energy solutions, someone who was curiously similar to themselves; for instance, somebody interested in technical gadgetry, thus implying that the technology would also mainly be geared towards such people. This type of "imagined user" represents a narrow understanding of society and has repercussions to how well the technology will function when enrolled to households, as well as to whom it speaks – meaning that there are potentials for unfair and unequal outcomes. Directly addressing this, Standal et al. (2020, p. 2) applied a gender lens to study prosumerism in Norway and the UK and concluded that 'policies need to be designed to promote new practices that are attractive for a more diverse group than today's standard subsidies and feed-in tariffs if the aim is to increase the number of residential prosumers and transition to a more sustainable and equitable low-carbon energy system'.

In a recent commentary, Nicholls et al. (2020, p. 181) confirm that there are still widespread issues connected to social impacts and control arising from smart home solutions: 'We are lacking ongoing in-depth analysis that seriously considers the negative potential social impacts of smart home technologies that we have outlined here and treats them as socio-technical issues in need of socially-informed solutions'. These considerations make questions such as: Is the idea of prosumerism a projection by the Resource Man? What does this entail for participation? In summary, therefore, understanding the variety of ways in which prosumer technologies impact the organisations of the everyday, gender relations and different age groups is central in order to gain better understandings of how these forms of technological arrangements can be implemented in a fair manner.

3.2.1 Flexibility, justice and demand response

The conceptualisation of prosumers as also relating to shifting, storing, saving and sharing energy means that we should look specifically at research that has addressed the social impacts of these types of smart, load-shifting technologies. As the availability of smart metres has increased, the provision of flexibility for grid and market purposes has been included as relevant for everyday energy users. This emphasis on flexibility has, amongst other things, made other energy-using and energy-saving technologies such as batteries or the rapid increase in the use of electric vehicles (EVs) more relevant as their potentially beneficial effects on the electricity grid could become unlocked (Skjølsvold et al., 2019). EVs have, therefore, become an integrated part of prosumer discussions, as they can be considered both a challenge due to higher loads when charging but also a solution due to their batteries and load-shifting abilities – e.g., charging at different points of the day (Skjølsvold et al., 2019).

Several studies have been conducted pointing out that the smart grid developments have been "top-down" with economic incentives and techno-centrism as the main focus and with a large variety of interpretations of core concepts such as users, flexibility, peak-demand shaving and shifting (e.g., Throndsen & Ryghaug, 2015; Throndsen, 2017). A particular strand of research has looked at the role of flexibility in particular. Powells and Fell (2019) coined the term "flexibility capital" for the purposes of understanding the justice aspects of implementing smart energy systems. Their point is inspired by Bourdieu's concepts of economic, social and cultural capital (Bourdieu, 1986), and implies that there may be situations in which a specific type of class or segment of the population have more room for using their flexibility than others. This is often connected to financial capital, implying that the more affluent typically have more energy technologies that can enable flexibility. That can lead to injustice, as described by Powells and Fell (2019): 'the level of service enjoyed by the more affluent may not simply be higher than those who are less affluent but may be directly enabled by reductions in the latter's comfort and/or convenience which may not feel fully voluntary' (p. 56). Fjellså et al. (2021) build on this conceptualisation in a study of smart energy systems in Norway and find that some households have more flexibility than others. What is more, flexibility "gone wrong" can lead to several potentially unfair situations, as they point out:

> *The flexibility project studied in this paper contributes to an individualization of a structural flexibility-problem and may add to the burden of unpaid domestic work for households with less available flexibility capital. We also suggest that flexibility work may be too easily added to existing load of unevenly distributed unpaid work within traditional households – often disfavoring women. (p. 107)*

This point has also been elaborated by Korsnes and Throndsen (2021), who show how prosumer pilot projects in Norway have a way of prefiguring certain types of solutions in front of other solutions. Preferred solutions are typically high-tech and capital-intense and can therefore be more appealing to those households that already are affluent, typically owning a Tesla and having rooftop solar PV installed.

In a somewhat different take, Blue et al. (2020) seek to reconceptualize the understanding of flexibility by moving away from an understanding of flexibility as achieved through price, technology or demand-side management, towards an understanding which connects demand with supply associated with the timing of when people actually need energy, and what they need it for. In short, perspectives such as "demand side management" take present-day needs for granted, and do not seek to find ways in which these can be altered. In other words, a preconfigured understanding of which variables can be altered (e.g., time, technologies and price) mean that forms of social organisation are held stable. Blue et al. (2020), instead, seek to understand flexibility as an outcome of connections between social practices (e.g., cooking, eating or relaxing), seen through two concepts: sequence and synchronisation. The implications of the reconceptualization are threefold. First, it implies that the supply and demand exist with a historical backdrop and a history which cannot be abstracted away. Infrastructures that were built for a purpose in the past might not have the same purpose today. Second, there is a so-called "performativity" associated with representations of what flexibility is about. This performativity makes it easier to imagine certain forms of change and flexibility compared to others. Instead, energy policymakers should focus on "redefining meanings of service and quality" (p. 17). The third implication they mention combines the first two in pointing out that we need to understand better how social practices link together in time. Instead of a narrow understanding of flexibility, this broader understanding has the potential to achieve a more widely understood realm for societal changes that can be beneficial in achieving actually reduced energy consumption. We will return to this issue in Chapter 5.

Lastly, going back to the original idea from Alvin Toffler (1980), namely that people more and more would stay at home, in "electronic cottages" as he called it, to work – which for instance would save a lot of energy on commuting to and from work, there is something to be said for solutions such as universal basic income and universal basic services, which is relevant for increased flexibility (see, e.g., Büchs et al., 2020). For instance, those that today are unemployed are more likely to be at home when the sun shines, and they can make more direct use of the electricity produced, compared to those that are at work. That could then make electricity cheaper for people with rooftop solar PV living at home in the daytime. Indeed, one thing that COVID-19 has led to is a larger share of home-offices, which has had an impact on energy use. According to the IEA, global electricity use declined during lock-down in March 2020, even though domestic energy use increased (IEA, 2021):

> *Electricity demand dropped to Sunday levels under lockdown, with dramatic reductions in services and industry only partially offset by higher residential use. When confinement was eased in Italy and Germany in April, electricity demand showed the first signs of recovering.*

This shows that the machinery that is needed to keep people at work, such as industry and the service sectors, is highly energy-demanding in itself. That implies that the goods and services used every day by humans have embedded energy implications that are not counted when energy efficiency is measured. In such a wider perspective, solutions such as universal basic income may lead to reduced global energy use because it could both lead to higher flexibility in the energy system, as well as a reduced number of people working for low-waged industrial facilities that mass-produce cheap consumer goods.

4 Prosumers and the Energy Communities Ecosystem

This chapter navigates through collective prosumer initiatives in the scope of renewable energy sources-based and decentralised energy systems. Energy communities result in societal dynamics centred on prosumer activities, which can challenge incumbent, centralised fossil-fuel energy systems and can foster a more sustainable energy transition. Collective prosumer initiatives span from the first community energy projects (with a diversity of examples from, for instance, Scotland, Germany, and Denmark) and larger community-led projects, including historical cooperatives in Italy and Germany, for instance, to modern-day REScoops (see Technological innovations and energy communities – from giants to ant-like networks). Altogether, the different types of energy communities make up an innovation ecosystem where prosumers play a central role leading forward the transition to a more decentralised energy system, but as well potentially contributing to mainstreaming low-carbon lifestyles and to a more democratic and just transition.

Although there is an increasingly standardised idea of what renewable energy communities are, there is not a blueprint for such community-led action, and distinct sociocultural, governance, and political aspects characterise these communities. There is little doubt that energy communities are relevant participants in an energy transition pathway where renewable energy sources (RES) and a more decentralised energy system lead the way forward. They have been characterised as a type of grassroots innovation (Seyfang & Haxeltine, 2012), and studied through a significant body of literature on 'community energy' (Bomberg & McEwen, 2012; Hargreaves et al., 2013; Walker & Devine-Wright, 2008). The expression "energy communities" has been as well associated with the emergence of the energy cooperative movement (Capellán-Pérez et al., 2018), and recently new definitions were coined through the European Union's Winter Package legislation (Inês et al., 2020), casting an additional layer of complexity on what "energy community" means. This chapter aims to characterise energy communities, considering different social, economic and technological innovation aspects.

4.1 From energy citizenship to community energy

Citizens are participating in the energy transition by engaging politically, adopting new roles in the energy system, and taking part in the setting up of various types of collective energy-related projects as users, consumers, prosumers, supporters, and even protesters. The idea of energy citizenship emphasises the awareness of citizen's responsibility for climate change, equity, and justice in relation to environmental and societal challenges, including energy poverty, energy literacy, as well as citizens' active participation in energy-related projects (Devine-Wright, 2007b; Ryghaug et al., 2018). However, this idea has been contested as one ignoring questions of access to resources and not accounting for a more inclusive perspective of who can effectively be an active energy citizen. As Lennon and colleagues argue (Lennon et al., 2020), citizens have been expected to play an active role in the transition, mainly through their purchasing power and investment decisions. That leaves out a wide range of increasingly disenfranchised and excluded citizens who have little resources to navigate through a complexity of financial, technological, and regulatory knowledge and resources needed to participate in the transition effectively. In this context, the need for a more decentralised electricity grid that aggregates dispersed, and localised renewable energy production opens new possibilities for an energy system with wider ecological and social benefits to citizens. Thus, a decentralised electricity grid connecting multiple prosumers is more than a technological design; it is also a new societal design with potentially socioeconomic as much as socio-ecological benefits to society. Indeed, an inclusive vision for energy citizenship may imply replacing giant power stations at the heart of the energy system by prosumers working collectively towards a common good – i.e., access to affordable and clean energy.

Community-led energy action refers to communities that come together to either develop new RES technologies and/or to produce, self-consume and share renewable energy, and to develop new solutions for energy efficiency, tackling issues such as energy poverty and aiming for a more sustainable energy system. Energy communities have a story that includes the widespread development of renewable energy cooperatives, but as well as other forms of localised community action (Bomberg & McEwen, 2012; Peters et al., 2010). Over the past decades, community energy has been a growing area of study in the scope of energy transition research (Bomberg & McEwen, 2012; Peters et al., 2010; Smith et al., 2016; Veelen, 2018). The roots of community energy can be traced back to the Alternative Technology movement in the 1970s (Smith, 2004), which focused on co-producing knowledge and developing new sustainable technological practices through a bottom-up action, such as the involvement of local communities in developing RES technologies to transition to a more environmentally sustainable society. Community energy emerges in the wake of this movement, evolving towards a more dispersed community-led action, and influencing grassroots innovations by reclaiming innovation processes with direct social and economic benefits for local communities (Seyfang & Haxeltine, 2012; Smith et al., 2013).

Grassroots community energy projects characterise a range of different initiatives, and have involved the participation of a wide scope of social actors (i.e., cooperatives, civil society organisations, schools, businesses, social enterprises, etc.) (Seyfang et al., 2014). Grassroots innovations are mainly place-based initiatives, and include energy generation as well as energy efficiency projects, ranging from the refurbishment of local housing to the adoption of new behaviours and practices, as is the case of Carbon Rationing Groups. These groups establish a carbon allowance for their members and collaborate to ensure group members reduce their carbon emissions, from electricity and heating to transport (Howell, 2012). Thus, although some community energy groups may be prosumers, who adopt different RES technologies (e.g., solar, biomass, wind, and small hydro technologies), community energy refers to a wider range of sustainable community-led energy practices.

Specifically, in the scope of energy generation, energy sharing and self-consumption, early research on community energy found that what differentiates these projects from other renewable energy installations mainly relied on the processes and outcomes that have been found to be specific to these communities (Walker & Devine-Wright, 2008). The process dimension refers to who is leading and managing the renewable energy project, while the outcome concerns the recipients of the project's benefits, which could be of both economic and social nature. Walker and Devine-Wright underline that community energy projects are unique not necessarily because of the technologies they develop or apply (e.g., decentralised, small-scale RES generators), but mainly due to the organisational and governance arrangements that characterise them (Walker & Devine-Wright, 2008). The degree of ownership has been one of the first indicators used to characterise community energy. Walker (2008) identified different ownership models, namely:

— Cooperatives, whose members co-own the renewable energy installations,

— Community-Shares, which refers to withdrawable share capital that can be applied through a cooperative or a charitable community benefit society,

— Development Trusts, a type of organisation that provides benefits to the local community but also to public administrations (usually community based and owned, although it can also be owned by a municipality),

— Shares owned by a local community organisation in a company that has invested in the renewable energy project.

These legal ownership models are based on examples from the UK, but there are similar types of models throughout Europe.

In community-led and place-based renewable energy projects, both the processes and outcomes would be focussed on creating local economic, social, and environmental benefits. By opposition, a renewable energy installation owned by a traditional utility company would not usually involve the local community in its investments and would primarily aim to generate energy to be sold directly in energy markets rather than providing economic returns to local communities. By making this distinction, Walker and Devine-Wright also find that different degrees of connection between local communities and RES generation and self-consumption exist (Walker and Devine-Wright, 2008). Nevertheless, a typical community energy project is driven by a local community, whose members may co-own the installation or manage the investments made by a third party and directly benefit from the energy locally produced, ideally both socially and economically (Walker and Devine-Wright, 2008).

The type of activity in which members may engage is also a criterion for characterising these communities. Community energy projects can be simply a community investment in a large RES generator that produces energy that is directly feeding the energy grid and sold in the market. In some countries (e.g., Portugal and Spain), this was the only possibility for community-led projects until collective self-consumption laws were introduced in 2019. The members of these communities are not RES prosumers in a strict sense (i.e., RES producers and self-consumers), but rather a group of citizens actively engaged in the production and collective financing of RES installations. Conversely, some community-led projects focus on self-consumption activities but also on energy efficiency through managing community trust funds for the refurbishing of buildings, for instance. There are various possibilities for prosumer-led organisational and business models that go beyond simple ownership of RES installations.

The way citizens are mobilised to engage in renewable energy communities has received some attention in community energy studies (Bomberg & McEwen, 2012; Gregg et al., 2020; Peters et al., 2010). Bomberg and McEwen identified two sets of resources that frame community energy mobilisation, namely structural and symbolic resources. While structural resources comprise existing institutional arrangements and the broader political context, including political support and appropriate regulatory frameworks, symbolic resources imply aspects such as shared community identity and the desire to be part of strong and resilient communities (Bomberg & McEwen, 2012).

Structural aspects were found to be critical and include political openness and the establishment of conditions that enable citizen groups to take advantage of opportunities (Fast, 2013). In the scope of EU Member States, structural political support implies a multilevel governance perspective. On the one hand, national energy policies need to integrate EU Directives, while national, regional, and local governments can actively promote policies that enable communities to overcome any regulatory and institutional barrier that they face. The simplification of administrative procedures, for instance, can make a difference for communities supported through the volunteering dedication of their members (Frieden et al., 2019). Direct state resources, including financial resources and in-kind incentives, such as administrative and technical support to develop projects, have also been important for the expansion of community projects.

However, soft symbolic resources were found to be equally fundamental to exploit opportunities derived from State support (e.g., in Scotland). Specifically, shared community identity and the search for sustainability and autonomy were identified as critical for mobilising local communities (Bomberg & McEwen, 2012). The example of Scotland highlights, on the one hand, the importance of regulatory, policy and governance frameworks for advancing community energy projects in Europe. On the other hand, it also clarifies the relevance of community trust, of local identities and the need for individuals to feel included and empowered to directly take part in energy-related decisions that affect their everyday lives.

Local community identities have also been characterised as being place-based, emerging from a sense of belonging and proximity (Bauwens & Devine-Wright, 2018). Here, community energy is also about empowering and building the capacity of local communities to actively participate in energy projects (Islar & Busch, 2016). A study of local community energy projects in Denmark and Germany found that citizens were more motivated by the benefits of their projects for supporting local economic development and community cohesiveness and empowerment rather than global sustainability priorities such as climate change (Islar & Busch, 2016). Another study of community-owned renewable energy in Germany equally concluded that local economic development was a key motivation for participating in renewable energy prosumer projects (Li et al., 2013). Other important incentives for participating which have been highlighted include lower energy costs (Horstink et al., 2020), as well as tackling energy poverty and promoting a more inclusive energy system (Khan, 2019). Autarky aspirations, namely the desire of being independent, self-sufficient, and autonomous, have also been found to play a crucial role in fostering social acceptance of decentralized energy systems, and motivating citizens' participation in both individual and collective projects, such as renewable energy communities (Ecker et al., 2017).

Considering their potential role for a more sustainable energy system, energy communities have been deemed central elements of a more democratic energy system, and RES prosumers have been characterised as an 'ideal citizen type' in the context of energy democracy (Szulecki, 2018). The argument relies on the ideal for a more democratic energy system governance that comes with the transformation of energy systems into decentralised and renewable energy-based systems. Citizens' political participation in the energy system implies they can be called to make decisions for the common good, rather than remaining passive recipients of a system that essentially provides for citizens' basic needs.

Participation in community energy projects also seems to promote more positive attitudes towards renewables and the energy transition in general. Bauwens and Devine-Wright's (2018) statistical analysis of the attitudes of members versus non-members of community-led energy projects found that members had more positive attitudes than non-members. The latter were not only indifferent but also uncertain about the relevance of renewables – wind energy, in this case (Bauwens & Devine-Wright, 2018). These findings added a new dimension to the relevance of citizens' participation in energy projects. Namely, citizens involved in community energy projects are more likely to support and accept the need for renewable energies and energy transition policies in general.

Community energy literature has additionally proposed a distinction between communities of interest, referring to groups with a common interest but who are geographically dispersed, and communities of place, which comprise groups of individuals that share the same locality and a place-based identity (Bauwens & Devine-Wright, 2018). This distinction is a critical aspect for understanding the differences between local community energy projects and national or regional community-led projects, which often adopt the cooperative model. The contribution to local economic development and the delivery of social and environmental benefits of community energy for local participating communities is a critical difference and a characteristic intrinsic to the early days of community energy projects. These features have been captured by the 2019 legal definition of Renewable Energy Communities (RECs) included in the REDII Directive. RED II stresses explicitly that the primary focus of RECs should be to deliver social, economic and environmental outcomes beyond financial profit to the local community (Campos et al., 2020).

Conversely, while the European definition of RECs fits well the description of communities of place, the aspect of proximity is not easily applicable to national renewable energy cooperatives, such as Eco-Power in Belgium, Enercoop in France, Somenergia in Spain, or Coopérnico in Portugal. These cooperatives, however, are key proponents of community energy and have, in some cases, started as communities of place. In the scope of the European Union Directives, national-wide renewable energy cooperatives fit well the Electricity and Market Directive definition of Citizen Energy Community (CECs), which will further be explored in Economic, social and environmental benefits of energy communities.

Still, more attention needs to be paid to the impacts of these initiatives, rather than a focus on the processes through which they emerge and develop (Creamer et al., 2019). Creamer and colleagues argued for the need to assess the broader costs and benefits of community energy for society at large. For instance, in what ways RECs impact those that are not able to engage or participate in them is a critical and still unexplored aspect. What is the impact of all types of energy communities on reducing the cost of energy and increasing environmental awareness? What impact do energy communities have on a more just and inclusive energy system? To what extent can they contribute to decarbonisation? These questions are critical, and there are still no clear-cut answers. Table 3 provides an overview of key definitions and categories of energy communities.

Table 3. Key definitions and categories of energy communities.

Definitions from the European Union's Winter Package Directives
Citizen Energy Communities (only electricity) A legal identity that is a) based on voluntary and open participation; effectively controlled by members or shareholders that are natural persons, local authorities, including municipalities, or small enterprises; b) primary purpose is to provide environmental, economic or social community benefits to its members or shareholders or to the local areas where it operates, rather than to generate financial profits; c) may engage in generation, including from renewable sources; distribution, supply, consumption, aggregation, energy storage, energy efficiency services or charging services for electric vehicles or provide other energy services to its members or shareholders (Art.2(11) EMD).
Renewable Energy Communities (electricity, heat, and cooling) A legal identity which a) in accordance with the applicable national law, is based on open and voluntary participation, is autonomous, and it effectively controlled by shareholders or members that are located in the proximity of the renewable energy projects that are owned and developed by that legal identity; b) the shareholders or members of which are natural persons, SMEs or local authorities, including municipalities; c) the primary purpose of which is to provide environmental, economic or social community benefits for its shareholders or members or for the local areas where it operates, rather than financial profits (Article 2(16) REDII)

Categories of Energy Communities	
Renewable energy sources (electricity, heat and/or cooling)	— Solar Thermal — Photovoltaic — Wind — Biogas — Hydro energy — Hydrogen
Territorial aspects	— Communities of Place – Local Energy Communities — Communities of Interest

Categories of Energy Communities	
Organisational typologies and legal forms	— Cooperatives — Social enterprise — Civil society organisation — Public-private partnership — Municipality or local government — Small enterprise
Activities	— Energy generation — Energy self-consumption — Energy supply, including through power purchase agreements — Energy storage — Energy sharing — Management of community energy grids — Energy distribution — Smart grid integration — Monitoring of network operations — Flexibility services — Aggregators — Energy efficiency services — Digital energy services — Car sharing — Operation of charging stations
Ownership	— 100% community-owned — Community shares — Development Trusts — Shares owned by a local community
Market models	— Peer-to-Peer (full P2P; Community-Based P2P; Hybrid P2P) — Power Purchase Agreements and Export Prices (these prices reflect the value of the exported power to a licenced utility) — Aggregators — Collective self-consumption — Virtual power-plants
Technologies, innovative concepts, and architectures	— Flexibility, — Demand-side management — Demand-response — Distributed Ledger Technologies — Blockchain Technologies

Categories of Energy Communities	
Policy Incentives and support schemes	— Surplus Power Tariffs (a fair remuneration for surplus energy not consumed or shared) — Net-billing (payment for energy exported to the grid, or deduced from energy bill) — Feed-in-tariff (payment received by the prosumer, generally higher than what could be earned selling power in energy markets. It is being discontinued by EU Member States) — Net-metering (prosumers are compensated for energy generated over a period).

Source: European Union's Winter Package Directives.

4.2 REScoops: the new wave of renewable energy cooperatives

Cooperatives are different from other companies in that their shares are co-owned by members rather than investors. Their key defining features include membership control of the cooperative: control rights are exercised democratically, based on a "one-member, one vote", and membership is open and voluntary (Kalmi, 2006). The first cooperatives emerged in the 19th century as a business model with the potential of offering better conditions and opportunities for those who faced harsh working environment, and as an alternative to large monopoly companies. Throughout the early 20th century, cooperatives proliferated across Europe in different industry and agriculture sectors. This cooperative movement also shared political hopes for transformation, which offered a business model based on a more egalitarian society, with potential social as much as economic benefits for participating citizens and contributing to alleviating poverty. Nevertheless, the first wave of the cooperative movement largely died out with the Second World War and, in some countries, they became negatively associated with oppressive communist regimes although, ironically, they had emerged as an instrument to counter the power of monopolies (Beggio & Kusch, 2015; Kalmi, 2006). The past two decades have instead witnessed a rise of the cooperative movement, mainly in the energy, food, and housing sectors, where strong networking, coordination and governance have been key.

Thus, in the scope of the energy system, the cooperative model itself is not new, and in some countries such as Germany, Italy, Switzerland and Spain, cooperatives have been present since the early days of electrification, as citizens took upon them the development and investments in local energy grids (Cuesta-Fernandez et al., 2020; Holstenkamp, 2015). However, the adoption of the cooperative model in the context of the production and (self-) consumption of renewable energy sources (RES), the so-called REScoops, has been more recently widespread. A study from 2018 found more than 2 500 energy cooperatives in Europe (Wierling et al., 2018), and the European Federation of Citizen Energy Cooperatives (REScoop.eu) lists in its website 1 900 organisation members, representing circa a million citizens (REScoop.eu, 2021c).

But what makes REScoops so attractive to citizens in the context of the energy transition? Some REScoops are local energy communities, but the majority are regional, national, and transnationally connected cooperatives. The liberalisation of the electricity market across Europe, together with the development of decentralised renewable energy systems, played an important part in the emergence of REScoops (Huybrechts & Mertens, 2014). Cooperatives arose largely as consumers aimed to take control over RES development so that "a democratic energy system, independent of giant corporations" could become the new paradigm (Campos & Marín-González, 2020). The issue of transparency, including transparency in decision-making and pricing, has been critical for new renewable energy cooperatives in Europe. REScoops such as Ecopower (Belgium) and Enercoop (France), who have been cooperative pioneers in producing and selling energy in the market, have tended to have lower prices than other companies, which represented a strong incentive to gather citizen support.

Despite their fast growth in the last two decades, cooperatives typically face several challenges, a key one being the attainment of sufficient capital to initiate their activities (Huybrechts & Mertens, 2014). Likewise, cooperatives are also challenged by organisational and managerial aspects since they often operate between volunteering-based and professionalised organisation models. Where they are located along this axis determines their ability to access new financial resources and to develop a series of activities that ensure effective day to day management, from communication and stakeholder engagement to their capacity to respond to the different stakeholder needs and effectively develop and manage RES projects (Herbes et al., 2017; Horstink et al., 2020).

However, through amassing support via strong networking activities, renewable energy cooperatives found innovative ways of overturning these challenges and taking advantage of opportunities. That was greatly aided by the cooperatives' values-set and "code" that foster a sense of solidarity among these enterprises. The key principles of the cooperative code in the new wave of REScoops reinforce the importance of: 'voluntary and open membership, democratic member control, economic participation by members, autonomy and independence; education, training and information; cooperation among cooperatives and a concern for the community's needs' (Beggio & Kusch, 2015). These principles echo different socio-political views that are relevant specifically for the energy transition, such as energy democracy and energy justice.

Thus, cooperation and solidarity between cooperatives offered opportunities for knowledge sharing and exchange activities that are critical for advancing with projects that tend to be largely volunteer-based. REScoop.eu, for example, offers a toolbox for REScoops that aims 'to support a local, community-led renewable energy revolution in Europe' (REScoop.eu, 2021b). Such cooperative solidarity means as well opportunities for accessing funding to support initial investments. In Portugal, for instance, the renewable energy cooperative Coopérnico, created in 2013, which had by 2021 about 2 000 members and a total investment of € 1 752 250 in decentralised renewable energy (PV), had a difficult time acquiring the necessary initial investments to kick start its production in 2013. Yet, Coopérnico received funds from other older and well-established European cooperatives such as Enercoop (France), Somenergia (Spain), Ecopower (Belgium) and Vebeurt (Netherlands). That was not an isolated event and represented an important strategy for the replication of the cooperative model across Europe. Another example is Energie Samen from the Netherlands, which is a national development and interest group for energy cooperatives managing a development fund for energy cooperatives to support the start-up costs of local cooperatives for sustainable energy projects. Overall, REScoop.eu has had a central role in activating the network governance effect that characterises this second wave cooperative movement in the context of the energy transition.

Despite the economic benefits of participating in renewable energy cooperatives, becoming a member of a cooperative still implies an initial cost for citizens, who will need to buy a variable minimum set of shares. This cost varies across countries and cooperatives. While in Belgium, Eco-power requires new members to buy at least one share (€ 250) with a limit of 20 shares per person, Enercoop (France) and Somenergia (Spain) each require that new members buy at least one share of € 100. These cooperatives may be able to sell energy at a more affordable price but also may not be able to compete with the prices of large utilities. Thus, such start-up costs are not without significance for lower-income citizens, even if they could benefit from lower energy prices when becoming clients/members of the cooperative. Membership costs also pose questions on the actual potential of inclusiveness of the cooperative model. For these reasons, renewable energy cooperatives have been placing increasing attention on developing solutions that tackle energy poverty.

REScoop.eu discourse on energy poverty contends that local energy communities can offer a mechanism to reduce energy poverty and ensure all citizens can participate and benefit from energy cooperatives. Some European cooperatives have been experimenting with different approaches to help tackle energy poverty, namely by providing advice on energy efficiency, supporting access to funds for refurbishing projects targeting low-income families, raising funds through micro-donations from cooperative members and, importantly, not cancelling energy supply to low-income families who fall back on their payments. Although significant, these measures are nonetheless piecemeal efforts, considering the complexity and heterogeneous manifestations of energy poverty in Europe and beyond (Bouzarovski, 2014; Day et al., 2016; Khan, 2019). Without targeted policies for energy poverty as part of national regulatory frameworks for energy communities, the potential of energy communities as an instrument to reduce energy poverty is still ambitious. Energy poverty is, however, a clear symptom of the injustices that are prevalent within the current energy system, which REScoops also aim to tackle by aiming for a more democratic as well as decarbonised energy system.

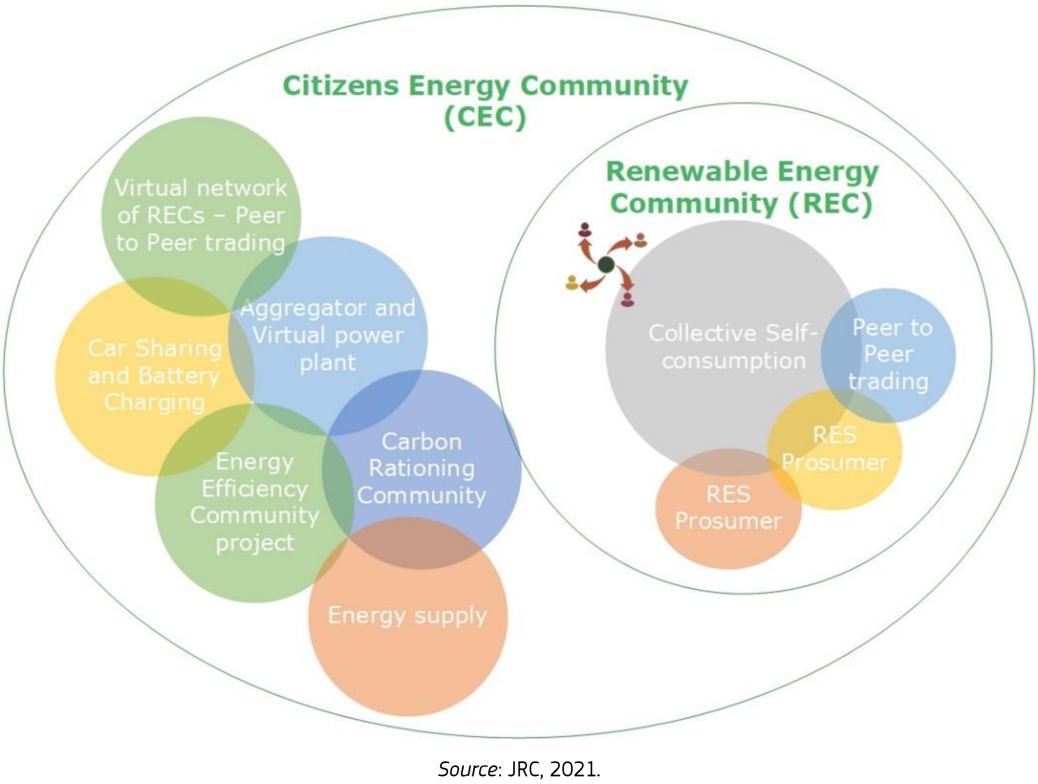
Moreover, the European Union has put forward a set of recommendations and instruments on energy poverty, such as the Green Deal's "Renovation Wave" (which aims to foster the renovation of private and public buildings across Europe), and recommendations for integrating principles of solidarity and social cohesion in the implementation of the Next Generation EU Recovery Package. Cooperatives are particularly well placed to take advantage of the opportunities that are come with these European policies and funding mechanisms (Commission Recommendation (EU) 2020/1563 of 14 October 2020 on energy poverty).

Cooperatives have equally an important role to play in raising awareness on issues that range from energy sufficiency to energy literacy. Enercoop in France, which was created in 2005 and considers itself a "pioneer" in supplying green electricity, is a national cooperative with 10 regional cooperatives, and has inspired other cooperatives in Europe through its innovative activities to raise awareness and promote energy efficiency. Enercoop's "TupperWatt" initiative has been a success galvanising a discussion around energy efficiency. The initiative consists of informal meetings where people are invited to discuss their ideas and preconceptions of energy efficiency and learn together how to improve their homes and workplaces' energy efficiency, through implementing an array of simple measures.

Aside from economic aspects, the importance of contributing to a cleaner energy system has been found to be a significant motivation for citizens who join renewable energy cooperatives (Campos & Marín-González, 2020; Horstink et al., 2020). Much like the first wave of the cooperative movement, the proliferation of renewable energy cooperatives is framed by political perspectives. Nonetheless, these are mainly rooted in discourse around a more sustainable and democratic energy system in which citizens can participate in critical decisions regarding a common good (energy) while contributing to tackling climate change and advancing with the energy transition. The new wave of cooperatives is thus intrinsically linked to a drive for a sustainable energy transition and the need to accelerate climate action. Despite building on an (old) cooperative model, their features are innovative: these cooperatives actively establish national and transnational networks and knowledge sharing interactions, and altogether shape a transformative social innovation in the scope of the energy transition ecosystem (Pel et al., 2020).

Renewable energy cooperatives in Europe are part of a dynamic ecosystem of stakeholders, in which REScoop.eu plays a central role in orchestrating partnerships, proposing and developing new policies, delivering new tools, sharing relevant knowledge and information, and maintaining a shared discourse around key energy transition issues, from flexibility markets to new green hydrogen policies, through its policy advocacy activities, largely framed by an energy democracy approach.

Figure 6. Ecosystem of energy communities (including communities of place such as RECs, and communities of interest such as CECs), their potential elements and services.



Source: JRC, 2021.

Figure 6 illustrates the variety of business models and activities, organizational formats, including social and grassroots innovations (e.g., Carbon Rationing groups), which may benefit from adopting CEC as a legal form. It also illustrates the different activities that fall within the scope of a REC, which could be itself one of the activities of a larger CEC to which it belongs.

4.3 Economic, social and environmental benefits of energy communities

A key appeal of both Renewable Energy Communities (RECs) and Citizen Energy Communities (CECs) is that they should primarily provide "environmental, economic or social community" benefits rather than just generating financial profit. This aspect is part of both RECs and CECs' definitions. It becomes relevant then to understand what these benefits can be.

As regards the environmental benefits of energy communities, scaling up and replicability are critical aspects. According to a scenario modelling study for the uptake of prosumer technologies in Europe by 2050, renewable electricity produced by prosumers can amount to up to 60% of the total electricity demand of the residential sector, with the highest share of energy used for electricity (between 79% to 83% in the residential and tertiary sector respectively), and can reduce between 45% to 75% of CO_2 emissions in the electricity sector by 2050 (Doračić et al., 2020). Other environmental benefits are more scattered and difficult to quantify. For instance, some energy communities develop energy projects within a wider strategy to protect local ecological heritage. They depart from a holistic perspective that integrates the energy, water and food nexus as key interrelated elements of an environmentally sustainable system, particularly in rural regions (Campos et al., 2019). Other softer, yet increasingly important environmental benefits of energy communities, concern the ripple effects across other sectors in transition, such as food production and consumption, transport and mobility, and water and waste management. By raising awareness of the urgency of accelerating the energy transition and achieving critical climate goals, energy communities can trigger other sustainable practices and behaviours.

Economic benefits are likely the most studied and often cited benefits of energy communities. Nevertheless, there are still a diversity of views and perspectives on the range and importance of economic benefits for collective prosumer activities. Revenues that can be directly earned by prosumers will significantly vary depending on national regulations, existing incentives (such as feed-in-tariffs), and other tax incentives, as well as tariffs or taxes either paid by or avoided by prosumers. Benefits will also depend on the retail price of electricity and whether there is an export price paid for excess generation. Hall and colleagues provide an overview of these different pricing schemes and (dis)incentives (Hall et al., 2019) and propose 15 different prosumer business model 'archetypes' that are either in the market, in development or at a trial stage, which can offer different benefits, depending on national contexts. They find that the economic benefits of prosumer business models can also come from the introduction of aggregators, who can effectively contribute to the needs of electricity system operators by managing the flexibility of numerous small local prosumer-centric systems. Nevertheless, the socioeconomic impacts of prosumerism are still not effectively studied, particularly as regards the potential of energy communities for reducing energy poverty and providing more affordable energy to both those who participate and those left out of the communities (Berka & Creamer, 2018).

Nevertheless, though several benefits are still piecemeal and confined to specific projects and initiatives, the mainstreaming of community-led action and the scaling of these social, economic, and environmental impacts may be critical for reaching a carbon-neutral but also more inclusive society. In their different forms and typologies, from large REScoops to local place-based communities, energy communities can have a critical, and still not well understood, potential to unleash a societal transformation and further develop key social and human capital for wider adoption of low-carbon lifestyles. The social benefits of these communities, and specifically the softer benefits, such as learning about the energy transition, gaining awareness on the importance of tackling climate change, can have ripple effects across different social practices and lifestyles that altogether brings us closer to living well in a future society which undoubtedly will have to deal with a warming planet.

In what follows, the interrelations between different technological innovations and energy communities are considered. Table 4 provides a synthesis of the key economic, social, and environmental benefits of energy communities.

Table 4. Overview of the key economic, social, and environmental benefits that energy communities can provide to their members and society at large.

Type	Key Benefits	Description
Economic	— Reduce energy costs and/or new revenues from RES produced — Support local charities — Development funds — Crowdfunding and collective ownership	— Through net-billing, feed-in-tariffs (FiTs), net-metering, export price, and other prosumer-centric business models. — Cooperatives have invested in solar PV installations on the rooftops of charities to directly benefit these institutions.

Type	Key Benefits	Description
		— Cooperative solidarity includes funds to support new cooperatives and communities in kick-starting their activities. — Many cooperatives and energy communities use crowdfunding to finance their RES installations and provide sustainable investment opportunities to their members.
Social	— Network of piers — Sense of belonging and cohesion — Community support — Feeling of ownership and empowerment — Increase energy literacy — Environmental education — Awareness and understanding of climate change	— REScoop.eu and other cooperative and energy community networks are networks of citizens who share an ambition to contribute to the energy transition. — Symbolic resources such as a sense of belonging, feeling of ownership and empowerment have been found to be key drivers for participating in energy communities. — Cooperatives and communities are active in offering their members information on a range of themes, including energy efficiency, on the environmental benefits of renewable energies and on the importance of tackling climate change, but also of reducing fossil fuels and nuclear energy. Some cooperatives also focus on other sustainability themes, such as circular economy, gender equality and openly share their knowledge and tools. Thus, they are also knowledge networks, providing informal education to their peers and society at large.
Environmental	— Reduced CO_2 emissions — Protect ecological heritage	— Emission reductions are both direct (due to RES generation) and indirect (e.g., changing behaviours and practices, reducing energy consumption).

Source: JRC, 2021.

4.4 Technological innovations and energy communities – from giants to ant-like networks

As the digitalisation of the energy system advances, different technological solutions result from both Renewable Energy Communities (RECs) and Citizen Energy Communities (CECs). As explained in the above sections, REDII and EMD directives introduced the definitions of respectively RECs and CECs, which are examples of the wider concept of energy communities. These definitions provide a set of collective organisational principles and rules for energy-related activities across the energy sector that may be assumed by any legal form such as cooperatives, SMEs, NGOs, and others.

The activities that can be performed by these communities include energy generation, which implies community usage or ownership of a renewable energy sources (RES) generator, in which case energy can be self-consumed or directly sold to the market. Communities may supply energy through retail market activities which can be coupled with flexibility services. They can be involved in collective self-consumption or energy sharing activities through a collective RES generator. Communities may also be involved in ownership or management of community energy grids (electricity or heat), in providing energy services, such as efficiency, flexibility, storage and smart grid integration, as well as monitoring and managing network operations or financial services. In the case of electric mobility, these communities can participate in car sharing and other services, including the management and operation of charging stations (Caramizaru & Uihlein, 2020). Indeed, it is increasingly essential to consider electricity generation together with other energy system elements and activities, such as heat generation, electric vehicle charging, and buildings' energy efficiency. Collective prosumer projects can be transversal to all these sectors, and from a consumer's point of view, keeping the house warm and having electricity for using appliances are part of the same 'bundle' of everyday life practices (Shove et al., 2015). Thus, there is a wide range of activities in which these communities can be involved, and which imply a wide array of possibilities for technological innovation that is either triggered by or further developed to support different community projects.

The socioeconomic and organisational activities of energy communities are co-evolving in a changing energy system, technologically characterised by process of decentralisation, the adoption of distributed renewable energy generation, digitalisation, and the emergence of smart-grid features. (Howell et al., 2017). Several activities that now can be performed by RECs and CECs, such as energy supply and energy generation, have historically been implemented by large utility companies, with a profit-maximisation motivation and in the context of a centralised and fossil-fuel-based system. Thus, the sociotechnical transition that is underway is transforming our energy system from one led by 'giants' to one co-managed by communities which, from a complex systems' perspective, largely play a role of an 'ant network'. New needs and functionalities also emerge in the context of such 'ant-like' energy system. Activities such as energy sharing, flexibility aggregators or digital energy services have only recently become possible due to technological innovation in the domains of smart-grids and new data-driven management processes.

Furthermore, the social and organisational characteristics of different types of energy communities imply a wider adoption of more open, collective, and democratic models for participating in the energy system. Accordingly, attributes such as flexibility, adaptability and openness to innovation may place energy communities in a privileged position for driving the adoption of several technological innovations, mechanisms, business models and architectures that are intrinsic to the current development of decentralised and networked smart-energy systems. Demand flexibility, Peer-to-Peer (P2P) energy sharing and prosumer-centric energy markets, as well as innovative applications of Distributed Ledger and Blockchain technologies to energy systems operations (discussed more in detail below), are among the key technological innovations and mechanisms that not only emerge in such ant-like system, but also may foster the emergence of new organisational designs in energy communities.

As regards the topic of demand flexibility, demand-side management and demand response make up a key set of adaptation mechanisms that are critical so that a large amount of RES production may be integrated into the power grid. The integration of renewables produced in different locations implies a variety of energy loads, which make system management much more challenging. In this context, demand-side management and demand-response are two connected concepts and are part of the broader concept of demand management that considers the consumption dynamics of the energy system as a flexible element. Therefore, demand management implies a set of actions taken by an energy prosumer (either human-driven or automated) that change the load consumption pattern following external signals such as energy prices or production profiles. This management can imply switching on or off appliances, machines, heat pumps, charging or discharging storage systems and electric vehicles, among others. It may also mean delaying or advancing the operation timings of different devices. With demand-side flexibility, prosumers assume an active role in managing their consumption patterns. Demand-side management actions may also be used to reduce peak demand (providing services to the grid) and improve the overall efficiency of the energy system, but also to maximise self-consumption by matching consumption to periods in which RES production is at its highest. At lower tension levels, prosumers can choose to use their home appliances at mid-day when their PV system is producing more energy or at times in which energy is cheaper.

Business models based on demand flexibility are potentiated by smart-grids communicational and computational features allowed by an ICT infrastructure such as sensors and actuators that allow for device control and monitoring. This enables the communication between prosumers in P2P networks or in an energy community, but also between these networks and grid and/or market entities (REScoop.eu, 2021a). According to a REScoop.eu paper on flexibility services, renewable energy cooperatives can benefit from several flexibility-based business models. Some of these models are especially important for RECs and CECs. For instance, collective-self consumption schemes allow a group of consumers to share a common RES generator. These may be a group of houses, a residential building, or a group of different local agents like schools, hospitals, public services, and SMEs. By applying demand-side management actions, an energy community may match its load, which, in the case of a solar PV-based energy community, implies displacing consumption to the sunny hours of the day. Or, if the different members of the community have diverse consumption profiles (for instance, a school, versus a household or a hospital), which is beneficial for a collective self-consumption model, loads can be distributed and managed within the community with the end goal of consuming as much as possible every kW/hour produced.

Energy communities such as CECs can also be acting as flexibility aggregators, which means they aggregate and manage a large total amount of loads. This is relevant because if a large quantity of appliances is aggregated and managed simultaneously, this may account for a sufficient capacity that may be leveraged to provide grid services to the Distribution System Operators (DSO) and the Transmission System Operators (TSO). Another possible model for aggregators (retailers) is to control the consumption to make it match the periods of lower cost in wholesale electricity markets by using dynamic electricity tariffs.

Although the previous business models may be performed by conventional market actors, CECs may have an advantage in developing them because they are in a privileged position to engage citizens to enrol in flexibility models for reasons other than financial profits (energy transition, sense of community, and trust or shared goals). There could be an increased potential for collective flexibility in a cooperative organisation, which is beneficial in an aggregator business model. Also, if flexibility is performed by a CEC, the members are likely to gain a sense of control of their energy consumption, which may lead to additional environmental benefits due to consumer efforts to reduce their energy consumption. Indeed, a study of customer preferences in the context of P2P exchanges found that 77,4% of a sample of 301 individuals in Germany were willing to participate in new P2P trading mechanisms (Hahnel et al., 2020).

P2P trading is one of the most promising activities that can be performed by energy communities. P2P implies the direct selling of energy between market participants or, indirectly, through an aggregator. The concept emerged in computer science and is defined as a distributed network architecture in which the peers act 'simultaneously as resource providers and resource requesters' without a central entity (Schollmeier, 2002, p. 2). With this definition, the application of peer-to-peer models to energy trade in community energy arrangements is straightforward in the context of prosumerism. Giotitsas and colleagues, for instance, propose a commons-oriented energy production system composed of microgrids organised in a peer-to-peer structure (Giotitsas et al., 2015). Sousa and colleagues present several designs for prosumer-centric energy markets, exploring how prosumers can share their production and investment (Sousa et al., 2019). In this study, sharing is enacted through agreements between peers who buy or sell energy from each other, or the so-called Power Purchase Agreements. This model is strongly based on a cooperative approach across the systems, which can have a positive social impact by empowering small prosumers. In the same study, three main structures for peer-to-peer markets were identified (Sousa et al., 2019, p. 367):

- A "full peer-to-peer", in which peers directly negotiate with each other;
- A "community-based market", in which a community manager trades within the community and operates as an interface with the rest of the energy system;
- A "hybrid peer-to-peer" market, which is a combination of the previous two.

In a study of homeowners' willingness to trade energy in P2P networks, Hahnel and colleagues (2020) found that most participants (i.e., 77.4%) were willing to partake in P2P energy trading. However, trading decisions could be affected by individual differences in loss aversion, for instance, in some cases when batteries were used, trading preferences changed, and homeowners were less willing to provide electricity to the community. Thus, these authors identified four target groups with distinct trading preferences (Hahnel et al., 2020):

- Price-focused prosumers (largely driven by the community electricity prices);
- Autarky-focused prosumers (more interested in producing, storing and self-consuming renewable energy);
- Classic non-trading consumers.

Thus, much like the different organisational and legal forms that energy communities may adopt, different technologies for energy communities will emerge in relation to different market models and citizens' preferences. Peer to-peer models have been applied to contexts that closely relate to specific activities such as the management of community-owned microgrids, with economic benefits for the communities involved, mainly by reducing their energy bills (Long et al., 2018).

Blockchain and Distributed Ledger Technologies have become in recent years a "hot topic" in power systems management and operation, with several applications and projects appearing in the market and academia. Distributed Ledger Technologies are immutable and synchronised databases distributed over a network of untrusted nodes which are comprised of three features, namely:

— A peer-to-peer network through which peers interact with each other;

— A distributed data ledger for storing data;

— A consensus mechanism that allows for transactions in a distributed manner (Hrga et al., 2020).

Blockchain is a specific type of Distributed Ledger Technologies, which consists of a shared and distributed database that contains a vast accounting record of transactions and tasks performed, alongside their chronological order. Such transactions are aggregated in blocks that are time-stamped and cryptographically linked to previous blocks forming a chain of block records which is called blockchain, because it shows a sequence of ordered blocks, each with a register of specific time-labelled transactions (Andoni et al., 2019; Kounelis et al., 2017).

Thus, blockchain can potentially provide useful instruments to ensure democratic and open decision-making mechanisms within different types of energy communities, as well as enable a mechanism that effectively registers and tracks all transactions and informational exchanges, which is critical to ensure transparency and openness in the management of information and data. When compared with the mainstream functioning of the energy system, these technologies are truly transformative from a societal perspective as they enable equal participation and the co-management of secure community transactions that would not be possible in a centralised energy system. Thus, blockchain can be considered as a socio-technical innovation, which has the potential for radically transforming social relations among different actors participating in new energy systems.

Peer-to-peer energy trading can greatly benefit from blockchain and offers a use case to analyse the key advantages of this technology. One advantage is that blockchain implies the absence of intermediaries, which are not needed for transactions (this is optimal, for instance, for peer-to-peer energy community systems). Instead, transactions are co-managed by a set of digital users, who each have a copy of the ledger. This aspect also ensures resilience since there is no one central point of failure, and if one of the nodes does not provide data, the whole system will still be functioning effectively. Blockchain thus fosters user empowerment since data and transactions are fully controlled by users. Stored transactions cannot be altered or deleted, which enables users to effectively track all occurrences, making blockchain systems highly transparent, since every transaction is publicly visible, and any user can at any time access the history log of the transactions made. However, these transactions could be anonymized, which would reduce transparency, yet ensure the protection of personal data. Recent studies have found a wide range of blockchain applications in the energy sector, including activities related to energy trading and sharing, environmental management, electric mobility, and financing models (Gough et al., 2020). Other important functionalities in the context of the energy sector are energy transactions processing, documenting assets ownership and management, energy certification and verification, real-time monitoring and analysis of energy use, remuneration in real or virtual currency, organisation of P2P and collective self-consumption, among others.

Nevertheless, in the context of energy communities, energy trading is the activity in which these technologies will produce more impact. Blockchain technologies can be used to support direct exchange between prosumers participating in an energy community. In a scenario where consumers can receive energy directly from a local producer without central intermediation, as is proposed by Kounelis and colleagues (2017), automatic price negotiations can take place between parties to define the price of energy that will be directly traded. This is socially innovative since it implies that consumers can directly negotiate a price to pay for energy, leading to a more open, decentralised, prosumer-centric, and inclusive energy system. Blockchain technologies applied to the energy sector can thus be driven by social innovations such as energy communities. Equally, they can be an enabler for these types of communities by providing decentralised architectures that support collective trading and energy sharing.

However, blockchain technologies can similarly lead to a socially dystopic view where citizens become automatic respondents in a system that is intrinsically comprised by automated computational processes, with very little freedom to decide or participate, thus undermining the energy citizenship objective. Unless, of course, users and communities take part in the design and conception of such systems in a transparent way. The axis from a commons-based scenario to an automated and autocratic one represents the immense scope of possibilities for blockchain technologies, which can lead to extremely inclusive systems but also to highly privileged and exclusive ones. Often, the difference lies in the process of technological development. Here, co-creation and co-design approaches are critical to ensure inclusivity across all technological applications for renewable energy communities. For instance, the "Commons Stack" project uses blockchains to support communities 'in raising and allocating shared funds, make transparent decisions and monitor their progress in supporting the commons' (Commons Stack, n.d., Our Approach – Mission). A European Research Council grant, project P2PModels combines social research and open-source blockchain technologies to foster social and economic justice (P2P Models, n.d., Manifesto).

In this sense, blockchain as a buzzword in the decentralisation movement is equally iconic of the different pathways for community-based decentralised energy systems. The development of energy communities can lead towards a more inclusive and just energy system. Yet, it can also lead us towards a highly privileged system, where only those with access to required resources (investment, knowledge) can be part of energy communities and benefit from them, while those left out risk higher energy costs and/or less energy security. There can be multiple scenarios regarding how the transition will evolve towards inclusiveness or privilege, and technologies such as blockchain can help tip the balance, depending on what values and underlining socio-political views are guiding the application of these technologies. From the mere point of view of their energy sustainability, it has to be noted that blockchain technologies would probably deserve accurate assessments and more critical considerations, given the large amount of energy consumption presently associated with the employment of its cryptocurrency ([21]).

4.5 Values, synergies and interdependencies for multilevel action

A prosumer-centric energy system is far from being individual-centric. Instead, it will require an ecosystem of stakeholders and other communities to thrive towards a more sustainable energy system.

The energy transition is a moving target and energy communities, whether place-based such RECs or communities of interest such as CECs, offer immense possibilities for a more inclusive and democratic energy system. Nevertheless, a wide range of possible pathways exists along different axes - from inclusion to privilege; from market-led prosumer businesses to community-led prosumerism; or from energy islands to full system interconnection (de Geus et al., 2021). Within these different dynamics, a range of various transition pathways for mainstreaming prosumerism may lead us towards a future prosumer-centric energy system. This was a critical finding from recent research, which unpacked the different pathways leading to the "mainstreaming" of renewable energy prosumerism, to conclude that, in its essence, different pathways reflect different underlying values (Pel et al., 2019). These values are negotiated between market, state (with a special role for local governments) and community interests. Values emerge within questions of how democratic the energy system should be, and how new collaborations and synergies can be negotiated through compromises and advancements towards different ideals for a more sustainable as well as more democratic energy system.

Values are important to ensure more inclusive energy communities. Attention to safeguarding that lower-income citizens can participate in these communities and that the different business and technological models implemented are transparent and democratic, requires embracing values such as democracy, inclusiveness, mutualism, among others. While the cooperative model supports these values, it can be challenging for cooperatives to enact truly inclusive processes, given their requirements and business models, but also the constraints imposed by the functioning of energy markets. For instance, cooperatives may not be able to have lower energy prices than those of large utility companies, which benefit from economies of scale with which new cooperatives cannot compete.

Cooperatives and energy communities can thus benefit from establishing new synergies, alliances, and interdependences with other community-led projects, such as energy efficiency projects, but also those operating in other sectors, such as food or housing cooperatives and social innovation initiatives. New energy communities can equally benefit from establishing synergies with ICT, developers and other stakeholders, ensuring new technological innovations are also more inclusive and effectively responding to real-life societal needs. Collaboration with policymakers at multiple levels of governance, but particularly municipalities, can also promote the upscaling and replication of energy community projects. Municipalities, who are often able to manage their own local energy grids, are in a unique position to encourage the development of local energy communities.

On the policy side, a new policy mix that promotes the adoption of renewable energy installations on both small and larger scales is fundamental to accelerate the development of decentralised renewable energy systems. This would require more support for small and medium-sized systems which could benefit from new Surplus Power Tariffs, providing a fair remuneration of the energy that is not self-consumed or shared within a

([21]) See, for example, a recent BBC article pointing to studies showing that bitcoin consumes annually a "similar amount of power to the Netherlands" (Rowlatt, 2021).

community (Petrick, 2021). New energy-related technology services also require the basic technical infrastructure – i.e., smart-meters – yet despite advancing with the transposition of the Winter Package policies, most EU Member States are not seriously engaged in rolling out smart-meters, yet. Without these new material infrastructures, new services, such as peer-to-peer trading and distributed ledger technologies, are not feasible. Thus, new policies need to skillfully integrate technological, economic, and regulatory aspects for the mainstreaming of renewable energy communities as central to a more sustainable energy production and consumption pathway.

5 Prosumerism and energy sustainability

Having presented various prosumer arrangements and conceptualisations, this section of the report starts thinking more specifically about how energy can become conserved and be used less instead of more. A broad range of concepts can be used to reflect on this issue, and we here look closer at the concept of sufficiency as elaborated in the next section. Energy conservation and reduction then goes more into concrete cases of what such a concept can imply for reduced energy use and prosumerism.

5.1 Sufficiency and needs

The concept of sufficiency is promising in terms of achieving consumption reductions, as it includes the possibility of having enough of something for a specific purpose (Darby & Fawcett, 2018). Sufficiency is sometimes argued as opposed to efficiency since efficiency efforts typically do not question and do not necessarily counter continued economic growth ([22]), which ultimately can lead to increased global energy and resource use (Princen, 2003). In and of themselves, energy efficiency efforts are narrow and ahistorical and do not question larger changes in levels of comfort in a society (Shove, 2018). For example, a fridge today is usually more energy-efficient, but it is also typically bigger, often ending up using more or the same amount of energy as an older and smaller, but less efficient one. That can also be said about a host of other technologies, such as TVs, cellphones and cars. Thus, increasing efficiency without attention to sufficiency can displace the problem of reducing resource and energy use. In order to get at sufficiency analytically, scholars often focus on the services that energy provides. For instance, sufficiency can be achieved by recognising the services that are provided by energy, such as light, heating, or cooling, and by suggesting policies that can ensure adequately tempered and lit houses without looking narrowly at singular technologies such as heat pumps or clothes driers (Wilhite et al., 2000).

A sufficiency analysis would also look at the reasons why the above-mentioned fridge has been increasing in size, and these could be connected to wider questions of urban food supply such as shopping habits (e.g., frequency, online, malls, etc.), and associated concepts of freshness and safety (Rinkinen et al., 2019). Failing to question the idea of desired services in the first place leads to a reproduction of increasingly energy- and resource-intensive ways of life (Shove, 2003). Sufficiency can, in this way, be understood as a concept that helps probe reductions in material and energy use without compromising life quality and wellbeing. That implies asking tough normative questions that involve negotiations between comfort and constraint. The normalisation of the idea that continuously increased production and consumption equal a better life – that more is always better – makes it more difficult to formulate a position wherein having enough is good. That is what sufficiency is all about: probing and formulating the idea that there is enough for everyone when a balance is made between 'too little' and 'too much'.

There is an increasing interest in approaches to sufficiency, but to date, there is no agreed procedure of how it can be studied (Spangenberg & Lorek, 2019). In general, however, it involves gaining an understanding of how we ended up where we are: how our needs and wants have become socially constructed through ever-spiralling increases in resource intensity leading to a normalisation of needs at unsustainable levels (Shove, 2003). A sufficiency understanding would, for instance, also recognise that energy use is connected to the sizes of our dwellings or TVs, and the number of technical gadgets we own. Needs are socially constructed, making the 'upper boundaries' of their supply fuzzy – are we talking about needs or luxuries (Wilhite et al., 2000)? Such questions are not easily answered with lenses that mainly looks at individual beliefs, attitudes or willingness to pay (Wilhite et al., 2000). For this reason, there is a need to understand the systems that took part in the co-production of those needs in the first place (Wilhite et al., 2000), which this report aims to do.

The sufficiency concept can then serve an additional purpose relating to participation and engagement. Whilst efficiency focuses on reducing energy inputs without putting any limitation on outputs that are left free to multiply (e.g., in terms of multiplication of appliances, bigger houses, bigger cars, etc.), sufficiency focuses on limiting energy outputs. This aspect opens up a discussion of how, contrary to efficiency approaches (that necessarily involve and rely on energy and technical expertise), sufficiency-related approaches can be more genuinely political and be more easily implemented by citizens without technical support. As pointed out by Korsnes and Throndsen (2021), people who participated in Norwegian prosumer-pilot projects were generally only happy to do more work to make their technological setup functional in their households and neighbourhoods. Nevertheless, a very narrow technical focus foregrounded highly technical solutions such as a power tariff or a combined heat and power device, and backgrounded solutions argued by the local communities

([22]) On this point and on the possibility of decoupling economic growth from resource consumption growth through efficiency, see EEA (2021).

that went beyond heating and electricity, such as growing local food, and reusing rainwater and sewage. Re-organisation of (energy) outputs as, e.g., entailed in the re-organisation of mobility in a city, shopping, eating, etc., is a political matter that can be dealt with by people – with some organisational assistance from governments and NGOs. Energy efficiency increase is instead typically a technical issue to be dealt by experts, where people are typically on the receiving or consuming end of the value chain (as elaborated in Sociotechnical configurations of renewable energy generation).

5.2 Energy conservation and reduction

Thomas et al. (2017) defined three basic principles of how sufficiency can be achieved: reduction, substitution, and adjustment. Assessing the potential for reduction entails reducing sizes (e.g., the size of a house or the number of rooms heated). Substitution involves assessing alternatives and could mean substituting some technologies and practices with others, for instance, moving from the current situation where everyone washes and dries clothes at home to more shared, communal facilities. Adjustment is about tweaking services to match new and less energy demanding habits and could, for instance, involve wearing an extra layer of clothes instead of heating a whole room or a whole house. One policy investigated by Thomas et al. (2017), for instance, was the possibility of implementing a cap-and-trade system for electricity sales. The policy is explained in this way:

> *In the beginning, certificates are produced for the total amount of allowed electricity sales in the starting year and allocated to suppliers based on their number and type of customers. This total amount of certificates will be reduced in subsequent years, following a pre-determined path. Suppliers will have to hand in the exact amount of certificates matching their sales each year. If a supplier meets its target, i.e., the number of certificates allocated is the same as its electricity sales in kWh, there will be no need for further action. If the customers saved more energy than targeted, the supplier may sell surplus certificates or bank them. If a supplier cannot motivate its customers to realise enough savings, it will need to purchase the missing certificates from other suppliers with a surplus. This trading element can therefore create flexibility and improve economic efficiency. (p. 109)*

They find that such a policy would be both legally and practically feasible in Germany and would affect energy efficiency and sufficiency if sales caps are set ambitious enough. Nevertheless, they point out that several aspects of such a scheme would have to be elaborated on to make it work.

There is currently some research ongoing that is testing the outcomes of a more sufficiency-oriented policy in connection with household energy use. A case from Switzerland presented by Dobigny and Sahakian (2019) aims to cater for reduced purchasing of household items and increased sharing in a community – facilitated in a simple way. In this case, sharing of tools and other items were facilitated in a neighbourhood by using simple stickers on mailboxes, showing which items (e.g., a drill, a ladder, toys, etc.) the households were willing to share. Such projects are deliberately addressing reduced consumption as an aim, as each household would not have to own, e.g., a full tool-set. A more recent example is from the H2020 project ENERGISE, which organised living labs with the intent of rupturing everyday life habits and practices (Sahakian et al., 2021). The project is innovative in prompting more than 300 European households to consider less energy-consuming ways of doing laundry and keeping warm. One of their findings was that these households could change habits and reduce energy use without complex technological set-ups. According to their report, they were able to reduce indoor temperatures by at least 1°C in living rooms and 1.5° in bedrooms, and all households were able to reduce laundry cycles by at least one per week (Sahakian et al., 2021, p. 10).

Speculating with somewhat more radical approaches and approaches that link us back to ideas presented earlier about social metabolism and what energy is actually for, De Decker (2020) presents some ideas around renewable energies and prosumerism. First of all, De Decker points out that if we did not need electricity to be present 99,9 % of the year, it would be much easier to reach a 100% renewable society. In De Decker's (2018) blog post, the idea is explained more in detail. In an example from Spain, he explains that 'decreasing the reliability from 99.75% to 99.00% produces a 60% cost reduction, with similar benefits for sustainability. Supply would be interrupted for 87.6 hours per year, compared to 22 hours in the higher reliability system'.

More generally, De Decker suggests that in the past, the economy was run more closely aligned with the rhythms of the weather and the seasons of a year – and it is perhaps in such a direction we might have to move in the future. Such a change would mean adjusting demand to fit supply, which would depend on the weather to get renewable electricity. Our dependence on "always-on" electricity has made us dependent on technologies that depend on electricity, which in turn has replaced practices such as 'washing clothes by hand, storing food without electricity, keeping cool without air-conditioning, or navigating and communicating without mobile phones' (De Decker 2018). Another interesting project by De Decker and Smets (2017) is the "human power plant", where the idea is to tap into the trend of staying fit and going to the gym and using the energy expenditure to produce energy for buildings. For this project, they are 'designing plans to convert a 22-floors vacant tower building on the campus of Utrecht University in the Netherlands into an entirely human-powered student community for 750 people' (De Decker & Smets, 2017).

All in all, the necessity of seeing energy provision and use in relation to each other, as is a central point of prosumerism, has the potential to develop energy practices that end up using less energy. Nevertheless, this is only possible if the already established comfort levels are questioned and if it is clearly pointed out and politically supported that a reduction in energy use is needed.

6 Policy recommendations and conclusions

It is helpful to recognise a broad understanding of prosumerism, including heating and electricity production and consumption, and the potential transformation of everyday habits that it can entail. Moving from approaches relying on incremental efficiency improvements to a more comprehensive understanding of prosumerism and of the question 'what energy is for?' can potentially lead to new opportunities for reductions in energy use, reductions in energy poverty, and to more multifaceted and locally adapted policy approaches. As this report has shown, a narrow understanding of energy prosumerism can instead favour technological approaches of the past and hinder really new sociotechnical arrangements actually enhancing energy sustainability.

There is a wide selection of opportunities for new prosumer arrangements, but some threats equally exist. Notably, the sociotechnical lens adopted in this report emphasises how a naïve and technocentric approach to the idea of prosumerism acting within neo-liberal markets entails the risk of reproducing producer-consumer relations formed in more centralised supply systems. These might be more capital-intense arrangements that could favour the already affluent, stimulate higher energy consumption, because of, e.g., economic revenues generated by sales of excess energy not used for self-consumption by energy prosumers or because of higher exchange rates of materials as generated by new information and distribution networks operating over larger and larger geographical areas, etc. Opportunities disclosed by a broader understanding of how energy should be produced, what it is for, where and when should it be produced (i.e., flexibility) may outweigh the threats, but the potential threats must also be thoroughly considered when developing policy.

The role of prosumerism in EU energy policy addressing citizen empowerment is then of particular interest for recommendations that focus on how to foster policies that can increase energy sustainability. Thus, a few critical final policy recommendations become relevant when it comes to a transformative pathway for prosumerism. Based on the review of academic literature, on the aspects discussed in previous chapters, and on feedback from four experts (see Appendix), we formulated the following policy recommendations.

First, a key recommendation is to apply a sociotechnical ([23]), rather than a technical or social perspective when assessing suitable policies to address energy prosumerism. As elaborated throughout this report, such an approach can generate new ways of transforming energy production and use. That is, for instance, relating to how publics can be understood as co-producers rather than mere 'acceptors' or 'rejectors' of renewable energy constellations (Sociotechnical configurations of renewable energy generation), and to how an understanding of what 'service' is provided and covered can lead to novel ways of appreciating the value of energy (Sufficiency and needs).

Second, we recommend focusing on the highly interrelated relationship between various initiatives that currently impact energy prosumerism. That relates to rolling out smart meters, arranging smart domestic energy use, the role of aggregators, and the connection with a bundle of renewable microgeneration, decentralised energy technologies. Such technological solutions must not only be targeted at higher income and affluent citizens, who already benefit from highly energy-efficient and renewable energy technologies, including for transport, heating, and cooling. Instead, a variety of technological arrangements should be promoted, for instance, through social housing, subsidies and other economic incentives, or be integrated in policy strategies that address poverty. This could also be combined with promoting and showing the large variety of existing solutions, as there is no "one-size fits all" in this regard (as the fashionable items of a Tesla and rooftop PV panel somehow indicate) (see also Korsnes & Throndsen, 2021).

Third, new energy system digital service technologies, such as demand-side management using blockchain, should ensure the participation of citizens in the co-design of automated systems that serve their present needs without constantly generating new and resource-intense ones (e.g., through algorithms and models that help optimising production and self-consumption), while supporting more democratic and transparent energy systems.

Fourth, to ensure actual reductions in energy use through sufficiency principles, we recommend looking for ways in which cross-sectoral policies can be informed by a reduction principle (e.g., reducing the size of houses, of appliances, of cars, or the number of rooms heated, or the number of used electronic equipment, etc.), by a substitution principle (e.g., substituting individual washing machines with communal ones in multiapartment buildings, substituting car with bike usage, etc.) and by an adjustment principle (e.g., wearing an extra layer of clothes instead of heating a whole room or a whole house), as outlined in Energy conservation and reduction.

([23]) Following the convention adopted in this report (see footnote 11) a sociotechnical perspective should be intended here as both sociotechnical (without dash) and socio-technical (with dash).

These new policies should particularly target higher-income citizens, for instance, by demanding that after a specific size, houses should be climate neutral. Furthermore, since solutions that are directed towards sufficiency (rather than efficiency) often require less capital to be mobilized, policies that are oriented towards sufficiency can be promoted in a way to help citizens co-ordinate to autonomously move in a direction that entails having and using fewer resources. The value of this is evident with a broad, sociotechnical understanding of prosumerism, as elaborated in Chapter 2.

Fifth, it is relevant to highlight the important role of energy communities in RES prosumerism. The various economic, social and environmental benefits that, as has been shown, energy communities can provide for their members and society at large can constitute the basis to formulate future policies at the national and European level. These should consider a new policy mix, providing incentives to RECs, such as reduced grid tariffs, new Surplus Power Tariffs, or help-desks at the local, regional and national levels to inform citizens of the administrative and technical requirements for setting up a REC. Such policies can ensure RECs are more accessible to lower-income communities, while accelerating the uptake of small and medium-sized renewable energy installations.

Sixth, European policies such as “Mayors Adapt” should encourage local governments to act as frontrunners in facilitating more inclusive decentralised energy systems through managing participatory budgets or other local energy transition funds, which can support the implementation of RECs in lower-income communities.

Finally, CECs (resulting from the transposition of the EMD) should not be confused with RECs or substituted by them, as CECs open the way to larger-scale citizen communities, including virtual communities and to a wide range of new business models, including aggregators and virtual power plants that are critical for replicating more sustainable decentralised energy systems. The new CECs regulation will be critical to foster the growth of renewable energy cooperatives (REScoops) across Europe, since REScoops often sell energy services but require a level playing field to compete with large scale utility companies, which the new (CEC) regulatory framework could provide.

In sum, in view of an energy transition, the energy sector will likely target more affluent customers, as they have the most extensive ‘flexibility’ potential and might be rewarded simply for being high-energy consumers—which could lead to a self-reinforcing spiral of escalating inequality and increased energy and resource use. Ensuring regular people’s engagement and enrolment requires novel thinking around how new technological arrangements can ensure good lives without invoking principles of scale-up and continually increased energy consumption. Such an endeavour implies asking tough questions about what energy is for and what types of problems different technological solutions are supposed to fix. Understanding the variety of ways in which prosumer technologies impact the organisations of the everyday life, gender relations and different age-groups is central to developing fair solutions that challenge well-established ideas of comfort and convenience that always see more as better.

This report has provided a first study of new forms of prosumerism and energy sustainability under sociotechnical lens that encourages a broader understanding of this concept. We believe that such a perspective can lead to a more multifaceted policy response that moves away from business as usual and towards more variegated and radical propositions for achieving sustainable energy use in the future.

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List of abbreviations and definitions

CEC	Citizen Energy Community
DSO	Distribution System Operators
E4S	Energy Shifting-Storing-Saving & Sharing
EMD	Internal Electricity Market Directive
EV	Electric vehicle
NGO	Non-governmental organisation
P2P	Peer-to-peer
PV	Photovoltaic
REC	Renewable Energy Community
REDII	Renewable Energy Directive
RES	Renewable energy sources
SME	Small and medium enterprise
TSO	Transmission System Operators

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Annex: Expert opinions on energy prosumerism in Europe

Four academics with leading expertise in energy prosumerism research within the social science and humanities were interviewed for the preparation of this report. These four are: Jouni Juntunen, Michael Ornetzeder, Noel Cass and Louise Reid.

They were asked five questions each:

1. What is the most useful aspect of the prosumer idea?
2. Does it represent something new and useful? What would this be?
3. To what extent can prosumers be part of/support an energy transition?
4. What are the major barriers preventing consumers to actively control and manage their energy consumption, producing and selling energy and storing it?
5. What types of policies have been/would be useful to support successful prosumer projects?

The feedback from the experts is grouped below according to the topics that occurred during the interview. In order to ensure anonymity, they are organised so that it is not possible to see who of the four experts said what.

What is useful of the prosumer term?

In general, feedback from the four experts on what is useful about the prosumer term shows that the most significant benefit lies in the ability to open up discussions of energy production and consumption to wider debates relating to power struggles, to new forms of organising energy ownership, to not seeing people as 'passive dupes', and to find new avenues to reduce energy use.

> *One potential that prosumerism brings is the idea of lowering your consumption to what is available, which can have positive add-on effects. For example, if you have a wood pellet boiler that is using combined heat and power, then you also want to super-insulate your home.*

> *Distributed energy systems are getting more and more popular, especially the success of solar power is visible. What I have been interested in are the* ***power struggles*** *that can be seen. Who gets the benefits, and who gets the drawbacks? I felt the idea of prosumption was thought of in quite simplistic terms, and some of the social aspects have not been covered well enough. The environmental benefits, plus the social benefits, how you renew and shape the energy system – these things should go hand in hand. We have opportunities to change the system so that the benefits of production are distributed in a different way, and value is created in a different way. And one thing I observed was that in a material sense, we have a distributed production, but in terms of ownership, that was not the case. And this also includes autonomy: Yes, you might have the system on your roof, but you don't have the energy autonomy, yet. We have this opportunity to create a new system, but it seems like the capitalistic system manages to turn it into not becoming a big difference from the previous one. That is my main concern, but I am not sure how much this has been picked up in research. Much research has focused on new business models, but I think that the role of citizens, and how citizens have control in this should be of interest also.*

> *I think the prosumer term makes sense in the field of electricity, if people who are mainly consumers, private households, become part of a market, or add this second role as a producer. To sell something on the market, or to share something with friends. For me, the idea that* ***people have a different mindset or different values than companies****, this is what is new about the prosumer concept. Now it is used for many different things. Also companies can be prosumers, and maybe this is literally the case, but it doesn't make much sense from my point of view. Companies are already a business, and they want to sell something. Of course, they may consume the things they have produced themselves, but this is a different form of consuming, in my*

> *understanding. A company buys and sells something that is part of being a business. And this is different to private households.*

> *I'm quite surprised that it is not used more widely because what it does is that it breaks down some of that binary between producer and consumer. In the context of microgeneration, prosumption captures this dynamic, while only talking about consumption or only talking about systems and production doesn't capture that. The value of it is particularly clear when you are simultaneously both producing and consuming. Prosumption is also useful in getting at the active and passive nature of engagement with energy. Prosumption suggests a more active and engaged form of interaction, and* ***it gets away from the consumer as passive****. Using the concept of prosumption helps to challenge some of these ideas of active and passive and a simplistic divide between production and consumption.*

> *Another benefit of the prosumer idea is that it can challenge some of the notions of how consumers are imagined. And I hope that it can move us towards a more reflexive, deliberative mode of engagement with people, and challenging some of the dominant techno-solutionism ideas, or about providing more information. The value of prosumption is that it encourages a bit more reflexivity, and deliberative thinking around what the phenomenon is, so that we can develop better ways to engage people.*

Does it represent something new?

In particular, aspects relating to energy poverty, equality and justice appear to be better foregrounded when dealing with energy prosumerism, as opposed to 'regular' production and consumption of energy. One issue is related to already existing prosumerism-arrangements that are rarely featured in mainstream media and research.

> *For twenty years, I have been saying that we need to have research projects that look at people who are setting up low-carbon living in whatever way. People living in housing coops, people living in co-housing, community renewable energy projects, people living off-grid, people living in canal boats. There are all these different ways in which people are creating low-carbon lifestyles using technologies and changing how they live their lives. One of the major problems we have, I think, with low-carbon living, new ways of living with energy, and changing our life to fit the energy you can produce, is that* ***there is absolutely no representation of it in the mainstream media****. Nobody knows what's going on. Another problem is that most of the experimentation in low-carbon living is done illegally. There are people living in vehicles and vans all over the place. We don't know about it because it is largely illegal and frowned upon and deviant. People living in yurts, in caravans, and in all kinds of arrangements; for the most parts, it's illegal.*

> *One aspect that I have been annoyed with is that when we use subsidies to get clean energy, that those subsidies are actually going to the companies who do not necessarily need them. We could be much better at directing subsidies to places where we actually empower people, and we get environmental benefits as well.*

The feedback on poverty and inequality was related to low-income groups, and to social housing as one area where prosumerism could be beneficial.

Low-income groups

> *The prosumer idea works only for a specific part of society. It is not really a concept for poor households. At least with the framework conditions we have now. But because the main target group is private households owning something, ownership is central. Now, this is changing with a focus on prosumer communities, and this could change the*

> *framework conditions also for poorer households. From the economic point of view, **it was always about mobilizing private money**, and if households are poor, there is nothing to be mobilized. If you are a poor household, the last thing you want to be is a prosumer in a way. But having legal frameworks, for instance, for communities, if done in a smart way, could open opportunities also for low-income housing. This could lead to better access to energy, particularly in the social housing sector.*

> *Looking at the energy literature, a lot of the people who have microgeneration systems are people who are able to fund it themselves, and who have the capacity, cognitive abilities and the time to understand how these systems work. There is an inequality here, and we need to be careful with that when we talk about prosumption. The costs and the effort of getting these microgeneration systems up and running mean that **we are talking about a particular group of people**.*

Social housing

Talking about a UK project:

> *People who are in social housing are getting solar panels put on their roof, and the city council seems to be very progressive and positive on this. They were saying: "We're just trying to get as many solar panels on roofs of our tenants as we can, because that is what we have agency over". And then, the tenants get any electricity they use during the day for free. Anything that is produced from the solar panels is theirs, and whatever is left will feed into the grid. In this case, the social housing tenants get the direct benefit of the energy coming straight to them. This specific model is something that local authorities could roll out because they have the capital to do those kinds of investments in technology.*

On prosumers and the energy transition

The way in which prosumerism could be connected to the energy transition was by some of the experts framed as a way to 'unlock' a new group of investors into the transition, namely private households:

> *From a policymaker's point of view, prosuming has been a way to mobilize customers. To mobilize normal households to invest in energy technology. Or **to invest private money into the energy transition**. This is maybe the main reason to talk about prosumers, and maybe also to change norms and legislation for this kind of production. There is a lot of private money, and there are a lot of roofs. Private people calculate differently than companies. They do not expect a return of investment within three years. They are happy with ten years, or even 20 years. Policymakers know this. There is a business opportunity, but also an opportunity for an energy transition. And **there will be no energy transition without investments**. But if countries like Germany would get rid of coal or gas in the electricity system, then **there is a need to use private facilities, roofs, private houses, as a place to put PV systems**.*

Other experts highlighted the fact that the energy transition needs a broader understanding, something which energy prosumerism can open up for:

> *There needs to be a recognition that **there are multiple ways of achieving the transition**, and that sometimes learning from people about what they have done, and how they have done it, helps us to understand those phenomena better, and that might help us to find different ways of dealing with the energy transition. So prosumption opens up the plurality of how we can do that.*

Moreover, it was also pointed out that prosumerism can also provide benefits in fields that are not only relating to energy but also to the organization of everyday life:

> *If someone puts in a smart energy system, it could lead to improvements in energy use. For elderly people, for instance, who might not know how to use these new systems, a smart solution could be helpful, where the family can control the heating, for instance,*

> *from afar. It is an energy intervention, but **it can be repurposed for care objectives**. Not just to create efficiency, or save carbon emissions, but for other purposes as well.*

Major barriers

Some of the major barriers that were mentioned were related to the removal of incentives, planning, and the challenges of altering everyday habits.

> *One problem we are facing here in the UK is that the central government has removed the incentives, whilst the local authority has to show a return on investment, so now it no longer makes financial sense for local authorities to [support rooftop PV projects] although it would reduce carbon emissions and it would be good for those with energy poverty, and for the environment. Local authorities have to behave as a business with short time horizons, but these [rooftop PV] prosumer arrangements need long-term support over 20 years or so.*

> ***The major barrier is planning**. Planners ought to say that: «If you want to do something in a new way, you automatically get permission». And then it is only if you do something really stupid that we take the permission away. Some kind of permissive planning system is one. Another thing is to have the opposite, saying: «No, you cannot build new houses that we know is a very energy inefficient way of doing things».*

> *In terms of economy, a barrier is that it offers few benefits compared to **the hassle of changing your everyday life**. If, for instance, you have a spot price of electricity, and you optimize your consumption according to that. You could do the same according to the production you have from your own unit. Both of these are fluctuating, and if you try to adjust your daily routines based on those fluctuations, that might be quite a hassle compared to the savings you get. And **only very specific user categories are willing to do that kind of fine-tuning of their daily life**.*

> *There are inevitable demands for energy, which really need to be met. There is a fundamental level of need, and we can do more work around questioning that: what is the fundamental level of need, and how is that changing, how has it changed, what might it look like in the future? What we might think is necessary now might not be what is necessary then. So, this type of «future proofing» ideas might be important.*

> *The affordability of the prosumption schemes, and the effort involved in understanding it, having the time and capacity to deal with it, is what I would say are the main barriers. For instance, you need to spend a lot of time finding out if there are support schemes, if you are eligible, how to access them. Even for someone like me, I do research on this, and I own my own home, but I have a busy life, I work full time, I have a family – **it is really not easy to find out how to do these things**. Even if you have some knowledge.*

> *There might also be a fear of investing in the wrong type of technology, particularly when they are very new. So, **this culture of reviews**, where you get a good sense of what is good and what is bad, that doesn't exist for energy technologies. And this is not only for the technologies but also for the installers, for instance, who are they? Are they good? Are they reputable? Is it too much of a risk? That balance of risk is something that needs to be considered.*

Other identified barriers were connected to the role of monopoly and competition, and ownership structures.

Monopoly and competition

> *Another thing is that the energy industry is not the most dynamic industry. It is quite conservative and resisting change. Of course, much has happened, and it is going in the right direction. But they are still in a monopoly position, even in places that they don't need to be. And* ***they are making the life for prosumers a little bit hard****. This is particularly the case with heat production; there, we are still in the stone age. Heat networks, or district heating, are mostly closed. Another interesting comparison is with the ICT industry. There we can have competition and dig several cables to the same household, but for electricity you cannot do that. Why is this a wise resource use for the fibre cable, but for the electricity cable it is not? Clearly, some industries have been better at protecting their monopoly power than others.*

Ownership structures

> *It can represent something useful if the system is not harnessed for the businesses totally. I think there is no difference if the production facility is on the roof or a centralized place; the difference is connected to* ***who controls the production****. This might be a very Marxist thought, that who owns the production units matters, and then there can be a huge potential here if we enable consumers or communities to run their own production. In policymaking, there should be done more to enable that. So, ownership structures matter. And municipalities could potentially do more here. They have traditionally been quite active, utilities are often owned by municipalities. But then it can also become a «cash cow», do you want to squeeze out every penny from the utility because it is owned by a municipality that wants to avoid raising taxes. But municipalities could definitely take a more progressive role here.*

Policy suggestions

The four experts provided a wide range of suggestions relating to policy. Some of them pointed out that it needed to be clear what the policy wanted to achieve before it is formulated. Others pointed out the importance of right pricing, different market models, establishing local support offices, and making it easier to choose prosumer-solutions:

> *It is important to define the purpose of the policy in question. You get different outcomes with different policies. You might get a high rate of solar power production, for instance, feed-in tariffs can easily lead to a system where service companies come and make it easy for consumers to have solar PV through a so-called fee-for-service. But if you have policies that support the buying of units, for instance, the government reduces your taxes or similar, then the picture is turned upside down: households by themselves start thinking, is this something that is suitable for us? What should we buy? And they want to do it by themselves. Things can be done differently.*

> *Support mechanisms should also be slightly technology-specific, I think, because some are more mature than others. Heat pumps have had an amazing success in Finland, for instance.*

> *I think it is about prices. What is changed now is* ***the interface between the private and the public grid****. And shifting these interfaces, which allows for selling and buying electricity without paying special taxes or paying reduced fees to use the public grid. These are ongoing negotiations that make it easier for prosumers to be part of this market.*

> *My impression is that there is a strong push from the European Union that the member states should do something. They should come up with different market models, allowing*

*for a better integration of prosumers – **a large variety of possible options**. Make it more attractive for private households to be part of the market. Lowering taxes and reduced fees is a good entry point for this. If you really can save money for instance, and then it also becomes attractive for low-income households.*

*More collective approaches could help to spread the risk investments. For instance, more neighbourhood-based systems, or for municipal buildings, when you have several flats within one building, that can share the risks and costs. The issue with that is the organization of it can be tricky to achieve. So, having more support for those types of initiatives, where project officers or **local authorities would come in and manage the project on behalf of the people**. That would probably help with uptake.*

*More support could be provided where you have multiple owners within a single building, or where you have a semi-detached house, it would make more sense for them. Social housing organizations are doing this, and it is easier for them because they actually own the buildings. But where there is private ownership, it becomes more difficult to achieve. So, some sort of **intervention specifically to retrofit private homes, where there are multiple owners, I think there is a lot of potential there**. And it is not necessarily only about energy generation, but about housing improvement more generally, improving cladding or insulation, for instance.*

*It is not only about money, but the coordination of those types of activities; so, having policy workers, or somebody to manage those projects. For instance, where I live, we are social and visit each other in the neighbourhood, but if we were to think about some sort of collective generation scheme, that could put all of that at stake because somebody might be unwilling to participate, or they might be embarrassed because they don't have the financial ability. So, if there was one step removed, like **an organization or a system that would bring us all together** without that more confrontational thing, that would be a much better way of trying to organize it, rather than leaving it up to us as individuals.*

KJ-NA-30981-EN-N

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doi:10.2760/608826

ISBN 978-92-76-47146-2