EEA Report | No 01/2022

Energy prosumers in Europe
Citizen participation in the energy transition

European Environment Agency

EEA Report | No 01/2022

Energy prosumers in Europe

Citizen participation in the energy transition

European Environment Agency

Cover design: EEA
Cover photo: EEA
Layout: Formato Verde

More information on the European Union is available on the Internet (http://europa.eu).

Luxembourg: Publications Office of the European Union, 2022

ISBN: 978-92-9480-472-3
ISSN: 1977-8449
doi:10.2800/030218

European Environment Agency
Kongens Nytorv 6
1050 Copenhagen K
Denmark

Tel.: +45 33 36 71 00
Internet: eea.europa.eu
Enquiries: eea.europa.eu/enquiries

Contents

Acknowledgements ... **4**

Executive summary ... **5**

1 Introduction ... **7**

2 The EU on the path towards climate neutrality ... **9**

2.1 Transitioning from fossil fuel to renewable energy sources ... 9

3 Prosumption: what is it and how does it work? ... **13**

3.1 The different forms of prosumption ... 15

3.2 Current state of prosumption in the EU ... 17

3.3 The technical potential of prosumption in the EU ... 19

4 Prosumers in Europe: four illustrative case studies ... **21**

4.1 Som Energía: an energy community with more than 77,000 members in Spain ... 22

4.2 Schoonschip: a prosumer collective in the Netherlands ... 23

4.3 Hvide Sande Fjernvarme: consumer-owned district heating in Denmark ... 25

4.4 Compile — Luče: intelligent management of demand and supply in Slovenia ... 26

5 Key aspects affecting the choice of prosumption model ... **29**

5.1 Opportunities ... 29

5.2 Costs and benefits ... 30

5.3 Project scale and ownership ... 30

5.4 National and local policies ... 31

5.5 What prosumption type fits best? ... 31

5.6 Public institutions and utilities ... 32

6 Benefits, challenges and drawbacks of prosumption ... **34**

6.1 Benefits ... 34

6.2 Differences between prosumer models ... 36

6.3 Barriers ... 37

6.4 Drawbacks of prosumption versus utility-owned renewable energy production ... 41

7 How can policy affect prosumption? ... **44**

7.1 Prosumption in EU policy ... 44

7.2 How can national governments stimulate prosumption? ... 45

8 Looking forward: the role of prosumers in an increasingly sustainable energy system ... **48**

8.1 Further actions and research needed ... 49

Abbreviations ... **52**

References ... **53**

Acknowledgements

The preparation of this report was led by Javier Esparrago (EEA). The report is based on a study by Bettina Kampman, Joeri Vendrik, Nanda Naber (CE Delft), Jan George, Jenny Winkler, Barbara Breitschopf (Fraunhofer ISI), and Katharina Umpfenbach (Ecologic Institute), with the essential contribution of Mihai Tomescu (EEA). The authors would like to thank the Eionet network, as well as the European Commission, individual experts and EEA colleagues for their input and comments.

Executive summary

Introduction

Renewable energy is expanding across Europe, gradually replacing fossil fuel energy in providing electricity, heating and transport. Renewable technologies create new opportunities for citizens to become energy producers themselves and to actively contribute to the energy transition. This is possible, for example, when households and businesses install solar photovoltaic (PV) panels on their roofs or when citizens form energy cooperatives and build their own district heating networks. This type of active participation by citizens is called prosumption and people who actively engage in the energy system are called prosumers — terms that capture the concept that these citizens are both producers and consumers.

This report provides a broad overview of the topic of renewable energy prosumers in Europe. It explains why governments support this initiative, describes different types of prosumption and discusses the associated benefits and drawbacks. It also provides useful background information for the interested citizen and policymaker, as well as case studies to inspire readers.

Prosumers contribute to the EU's climate ambitions

The EU is committed to the goals of the Paris Agreement on climate change and is planning to become climate neutral by 2050. In addition, the invasion of Ukraine has highlighted the urgency to reduce dependency on Russian fuels and enhance the EU's energy security. Achieving these objectives will require a drastic transformation of Europe's energy system, both increasing its efficiency and boosting the deployment of renewable energy. As the number of wind turbines and solar panels increases, the energy system will become more decentralised with a large number of relatively small-scale production locations. Heating and cooling, as well as mobility, also need to decarbonise, partly based on direct electrification (e.g. heat pumps or electric cars), partly by integrating direct renewable energy (e.g. solar thermal or geothermal heating) and partly by using new energy carriers (e.g. hydrogen).

To achieve this transition, a sustained and joint contribution of citizens will be needed. Millions of EU citizens already support this transformation, for example by actively reducing their energy use, switching to renewable energy providers or choosing to lead more sustainable lifestyles. Increasing the number of citizens who participate as prosumers will only help this transformation, since this will further speed up investments in renewable energy production, electric cars, heat pumps and energy storage. From a technical point of view, almost every citizen in the EU can become a prosumer.

Prosumption exists in numerous types and forms: for example, it can be only one household, a group of tenants in a multi-family building or an energy cooperative with participants from the local community. They can produce renewable electricity, heat or both, and some combine this with supporting the grid infrastructure or providing energy storage. Prosumers can apply different ownership structures and business models, which may be run by volunteers or, in the case of larger projects, by paid staff.

Prosumption can have a wide range of benefits

Prosumption can benefit the participating individuals, as well as society as a whole. These benefits may be environmental, social and financial, but they depend strongly on the specifics of the project and on the policy framework that the government has put in place. Compared with projects run by utilities and other companies, energy generation by prosumers is typically more costly because of the smaller scale, but this also allows faster deployment in times of high and volatile energy prices. The social benefits can also be higher. Citizens can feel empowered and local energy communities can increase the sense of community. Public support for renewable energy can increase when citizens are actively engaged and profit financially from the projects. Critically, prosumer projects provide access to funds that would otherwise not be available for renewable energy. This can speed up the energy transition and reduce greenhouse gas emissions.

Nevertheless, citizens who want to initiate and implement a prosumer project are likely to face a number of challenges. The cost of the project may be too high, national regulations may not permit the prosumer model that would fit the situation or there may be insufficient volunteers prepared to put in the effort needed to develop the project. Lack of knowledge and expertise can also be an issue, since prosumption may require expertise in many different areas, including technology, policies, regulations and financing. These barriers can be reduced by effective policies and support frameworks.

How to decide which type of prosumption is best for a given situation

Given the range of prosumption types, technologies, policies and business models that exist throughout the EU, the opportunities for prosumers in a given situation depend on the specific circumstances. The main aspects to consider when deciding which type of prosumption would be best in a given situation are the following:

- **Opportunity**. First of all, practical, technical, market and geographical issues need to be considered. In what type of dwelling and neighbourhood does someone live? What area is available for the equipment? What are the climate characteristics and financial possibilities? Is it possible to gather a group of enthusiastic neighbours who want to cooperate? Perhaps a local or regional energy cooperative already exists that offers the opportunity to become a member. What are the relevant government regulations? Are there support policies in place?

- **Costs and benefits**. The financial costs and benefits of different prosumption types and energy systems will need to be carefully considered to identify options that are financially feasible in a given scenario. Non-financial costs and benefits can also be included in assessments, such as reductions in CO_2 emissions or the social and socio-economic benefits of a community project.

- **Project scale, ownership and legal form**. The scale of a prosumer project can vary widely, from an individual household that owns solar panels on the roof to a nationwide cooperative organisation. A larger-scale project typically has a larger impact on CO_2 emissions at lower unit cost but requires much more effort and more professional organisation than a smaller project.

Government policies are a key enabler of prosumption

Prosumption can only thrive where the government regulations allow it and where effective and stable policies are in place that support these developments. The EU provides the overall policy framework and targets, with a recent emphasis on prosumption as part of the REPowerEU plan (EC, 2022c). National governments apply these and implement specific policies tailored to their needs and specific conditions. Examples of effective policies are provided in this report.

Looking forward: next steps to further developing prosumption

The opportunities for citizens, businesses and public institutions to become prosumers will grow further in the coming years as policies improve and the cost of the technologies falls. Further research into the benefits and challenges can help drive these developments. We also recommend developing a system to monitor the progress and impacts of prosumption, in order to support policymakers in improving their policies and actions. Stakeholders can support prosumer initiatives by sharing their knowledge and helping new prosumers to successfully develop their projects.

1 Introduction

Renewable energy use is growing across Europe, gradually replacing fossil fuel energy. Consumers can actively contribute to this energy transition by becoming prosumers. There are many forms of prosumption throughout Europe that can have a wide range of benefits and added value under the right circumstances. This report aims to increase our understanding of prosumption and inspire readers to actively engage in local projects to boost the energy transition from the bottom up.

The growth of renewable energy is driven by the ambition to slow climate change and to contribute to a cleaner energy system. As the energy sources are indigenous, they are also key in ensuring the EU's energy security. Renewable energy source (RES) projects can be large-scale wind farms or photovoltaic (PV) plants, often operated by energy utilities. However, energy transition technologies also permit a large number of small-scale, decentralised projects. For example, PV plants can generate electricity on millions of rooftops throughout Europe, wind turbines may be owned by local energy communities or farmers, and district heating systems can be owned and operated by local municipalities.

Individual citizens, small or medium-sized companies and public entities that consume **and** produce renewable energy are often called **prosumers, energy prosumers** or **energy citizens**. In some cases, they may also provide energy services such as energy storage and demand flexibility. People can be individual prosumers, such as households or businesses with PV panels on the roof. Several households can also become collective prosumers, for example when they take joint action and install PV panels on the roof of a multi-family building. Throughout Europe, individual households have joined forces and created energy communities, for example in the form of cooperatives. These cooperatives can invest in larger-scale projects, such as a wind farm or a large free-field PV project, or take a range of actions to make their neighbourhood as sustainable as possible.

RES generation is often not the only activity that characterises prosumers. They can also invest in battery storage, heat pumps or electric vehicles. Some prosumers may contribute to the energy system by offering it demand flexibility. They change their energy demand in response to the fluctuations in RES generation or grid bottlenecks. Others own and operate infrastructure such as a district heating network or a local electricity grid.

All these different types of prosumption provide an opportunity for people to actively contribute to climate change mitigation and to the transition to a renewable and resilient energy system.

This report introduces the broad topic of RES prosumption in Europe. It describes what prosumption is, why governments support it and what the benefits can be for individuals and society as a whole. It also discusses the challenges that a much more decentralised energy system can create both for individual households and at the system level. It contains practical information for the interested citizen and policymaker, as well as a number of case studies illustrating how prosumption works in real life.

The report is structured as follows:

Chapter 2 describes the broader context for the growing number of prosumers in Europe, with an introduction to the climate targets and the energy transition that is needed to achieve these targets.

Chapter 3 explains what prosumers are, describes different types of prosumers and explores the future potential for prosumption throughout Europe.

Chapter 4 introduces four illustrative case studies. These show how citizens have come together and set up energy communities in four different EU countries.

Chapter 5 explores which aspects citizens need to take into consideration to become prosumers.

Chapter 6 provides an overview of the main benefits for prosumers and the barriers they may face. In this chapter, we also compare RES generation by prosumers with commercial projects.

Chapter 7 describes how government policies affect prosumers. As we will see throughout the report, effective policies can be crucial enablers for individuals becoming prosumers.

Chapter 8 recaps the report's main findings and outlines potential future steps to unlock the full potential of prosumption for decarbonising the energy system.

2
The EU on the path towards climate neutrality

The EU endorses the Paris Agreement on climate change and aims to become climate neutral in 2050. This will require drastic efforts to reduce greenhouse gas (GHG) emissions in the coming decades, in all sectors. Replacing fossil fuels with renewable energy sources (RESs) in the built environment, industry and transport sectors is a key part of this challenge.

Almost 200 parties, including the EU and its Member States, committed to the goal of the Paris Agreement, which is to limit global warming to well below 2 degrees Celsius and preferably to 1.5 degrees Celsius above preindustrial levels (UNFCCC, 2015). The EU fully endorses this aim (EC, 2020a) and has therefore set the target to become climate neutral by 2050. As an interim target towards that goal, a target to reduce GHG emissions has been set for 2030: at least a 55% reduction in GHG emissions compared with 1990. This was agreed in April 2021, as part of the European Green Deal, and will be translated into more detailed targets and policies in the coming years. For comparison, in 2020, GHG emissions in the 27 EU Member States (EU-27) were 33% below 1990 levels (EEA, 2022).

Achieving these targets will require a wide range of actions from policymakers, companies and citizens. Under current and planned policies, GHG emissions in the EU are expected to decrease by up to 41% by 2030 and by 54% by 2050, compared with 1990 (EEA, 2021a). This is clearly insufficient to meet the -55% target for 2030 and carbon neutrality in 2050: substantial additional effort is necessary.

Currently, the energy sector, which covers electricity and district heating, as well as transport, is responsible for the largest share of GHG emissions. Despite significant progress over the last three decades, energy emissions will have to decrease much further as we approach 2050. The challenges are particularly great in the building and transport sectors, since neither has yet achieved significant emission reductions — despite efforts to decarbonise both sectors (EC, 2020a).

2.1 Transitioning from fossil fuel to renewable energy sources

2.1.1 Renewable energy production will continue to grow

Energy use accounts for a large share of the EU's GHG emissions, amounting to 91% in 2020 (EEA, 2022). Other sources of GHG emissions are process emissions in industry and non-CO_2 GHG emissions, for example methane and nitrous oxide emissions in agriculture. Because of their dependence on coal, oil and natural gas, industry, the built environment (residential and commercial sector), mobility and power generation all contribute significantly to GHG emissions in the EU (EEA, 2021b).

One way to reduce these emissions is to reduce energy consumption, through energy efficiency measures and other types of energy savings. To this end, the EU has made the 'energy efficiency first' principle a key objective of EU energy policy (EC, 2022a). At the same time, however, the GHG emissions of the remaining energy use will also need to reduce over time to achieve the 2030 and 2050 climate targets. One key way to achieve this is through increasing the use of RESs and decreasing the use of fossil energy sources.

This is challenging, since renewables currently cover only 22% of the total energy demand in the EU (Eurostat, 2022). Furthermore, while public support for renewables is generally high, some oppose projects in their neighbourhood (see Section 6.1.2 for more information).

Wind and solar energy have the highest potential for further growth and are likely to dominate the future energy system. However, RES heat technologies will also play a key role, particularly solar thermal, geothermal and biogas combustion.

2.1.2 The energy system needs to change

The transition to a climate-neutral energy system through the large-scale deployment of RESs will drastically change the energy system. The main differences between the current fossil-based and the future climate-neutral energy systems are:

Driven by decarbonisation efforts, electricity is expected to become the dominant energy carrier supported by the growth of RES technologies such as wind and solar power. Natural gas and oil-based fuels such as petrol and diesel will gradually decline (EC, 2020a). Thus, the electrification of the energy demand is key to achieving full decarbonisation. Promising technologies to achieve this are heat pumps for homes, electric boilers for industry, green hydrogen and electric vehicles.

The current electricity system is demand driven, and production can be increased and decreased so that it follows changes in electricity demand. The future electricity system is supply driven. At any given point in time, the level of solar- and wind-based power production depends on the time of day, the season and the weather conditions. Production fluctuates and is not adjustable. As a consequence, demand has to be matched with supply, rather than the other way round (EC, 2020a).

In the current energy system, electricity production is centralised. Electricity is mainly produced in a limited number of large power plants that produce large amounts of energy. In the future energy system, electricity production will become more decentralised than at present, with a large number of production locations producing small amounts of energy. Photovoltaic panels on rooftops, but also larger wind farms in the medium-voltage grid, are examples of decentralised production (Horstink et al., 2019; EC, 2020a).

Today, a small number of commercial energy companies dominate the energy market. By contrast, decentralisation provides opportunities for a large number of parties to become stakeholders in the energy market (Horstink et al., 2019). Furthermore, local ownership is possible, which may have social benefits compared with centralised ownership by large energy companies (see Section 6.1.2). Even now, many more active players are involved than were a few years ago.

Today's heating sector is characterised by a large share of decentralised heating systems based on fossil fuels. In addition to electrification via heat pumps, the future heating sector is likely to feature more centralised heat generation and the use of waste heat distributed through district heating networks.

Given the right policies, these developments can drastically change the energy system. They create challenges that must be resolved and opportunities for innovative solutions. Some of the main technological challenges are detailed below.

Matching the supply and demand of energy, especially electricity, will become more difficult in the future as the share of renewables grows, since the electricity supply from wind and solar technologies is inherently variable. Matching supply and demand at every moment is essential to keep power grids stable (EC, 2020a) and is built on these prerequisites:

Demand-side flexibility, in which energy demand is adjusted to make sure it matches supply, can contribute to matching the supply of and demand for energy (EC, 2018).

Short-term energy storage, such as batteries, can be used to solve differences between supply and demand during the day or the week. Part of the energy produced can be stored in batteries or heat storage systems to cover the energy demand at night. Short-term energy storage may also be achieved through larger-scale solutions such as electrified district heating.

Long-term (and seasonal) energy storage is necessary to solve seasonal imbalances between supply and demand or to manage long periods of low generation or higher consumption due to specific weather patterns. Various energy storage technologies are being developed (see EASE, 2022, and EC, 2022b, for further details), with one promising example being the production of hydrogen from renewable electricity.

The transition from a fossil- to a RES-based system will also affect **energy infrastructure requirements** (EC, 2020a). The growth in both the demand for and supply of electricity requires reinforcement of the power grid and improved interconnections. A shift from individual heating to district heating requires new heat grids, and new energy carriers, such as hydrogen, may require new pipelines. On the other hand, part of the infrastructure for fossil fuels could be repurposed to carry new forms of energy. For example, natural gas grids can be partly converted to transport and store hydrogen ([1]).

([1]) The transmission system operator for gas in the Netherlands, Gasunie, has plans to convert redundant gas pipelines to hydrogen pipelines (Gasunie, 2022).

Finally, further **digitalisation** is likely to be key to managing all these technologies so that demand and supply are matched throughout the day and a stable and secure supply of energy is ensured. This enables **smart** management of grids, energy storage and demand flexibility options (Good et al., 2017; smartEn, 2020).

2.1.3 Towards a mix of large- and small-scale energy generation

This report focuses on RES prosumers and their role in this energy transition. However, prosumption is not the only solution. In the future, energy companies will still account for a large share of overall energy production in large facilities, such as offshore wind or large-scale onshore wind and solar farms. Both types of energy generation have their benefits and drawbacks; a comparison can be found in Section 6.4.

Since technologies are still evolving and innovative solutions to future challenges continue to be developed, it is not yet clear what the future mix of centralised and decentralised energy generation and storage will look like. It can be expected, though, that to achieve ambitious climate targets, we need to combine both, making the most of the synergies between them.


© Mischa Frank, Unsplash

3
Prosumption: what is it and how does it work?

Renewable energy source (RES) prosumers are individuals or groups that both consume and produce RES-based energy or offer energy services to the system, such as flexibility or storage. Unlike utility companies, delivering energy services is not a prosumer's main commercial activity. Throughout Europe, the prosumer concepts exist in numerous forms, and they can be characterised by several attributes, such as entity, technology or business model.

We define RES prosumers as entities — individual people, collectives, households, small and medium-sized enterprises (SMEs), schools, hospitals, etc. — that are active in the energy system in different ways, for example by both consuming and producing or only producing RES-based power or heat, by offering energy services such as demand flexibility or storage, by being involved in an energy community, or by owning and operating grid infrastructure. This definition of prosumer projects also includes cases of virtual transfers. Similarly, we understand financial investments — even in plants located far away from one's home — as a contribution to production from RESs, and these investments may take different forms, for example equity or loans. Energy system services are included in the definition, because they contribute to the integration of larger shares of solar and wind energy in the energy system as a whole (as explained in Section 2.1.2) ([2]). This definition aims to capture the wide range of RES projects and initiatives with a large degree of citizen participation.

Not all entities that consume and produce renewable energy or provide energy system services are considered prosumers, however. For example, industrial companies that produce part of their own energy are not considered prosumers, because they do not directly represent citizens ([3]). Other, more indirect types of citizen involvement are also not included in the definition, such as cases where communities receive part of the profits of a local wind farm without being actively involved in the project (Maleki-Dizaji et al., 2020).

Throughout Europe, prosumer concepts exist in numerous types and forms. Many individual households have become prosumers, as have groups of people such as residents in apartment complexes or individuals who join energy cooperatives. Furthermore, prosumer projects can have different types of ownership structures and can make use of different technologies. Table 3.1 gives an overview and examples of the main attributes.

([2]) Storage options are included in our definition of prosumers only when they contribute to the integration of renewable energy. Using a battery for commercial activities such as trading energy or frequency containment services is not considered prosumption.

([3]) These types of actors are classified as 'active customers' in the EU Electricity Directive (EU, 2019) (Article 2(8) Internal Electricity Market Directive), but are not included in the definition of prosumers used in this report.

Box 3.1 Prosumers, self-consumers, energy citizens, renewable energy cooperatives, energy communities: different names for the same concept?

What we call prosumers in this report is defined in the text. However, the reader should be aware that other authors apply other definitions to the term prosumer, for example by considering a more limited scope and including only those consumers who also produce energy, and not taking other energy services such as energy storage or demand flexibility into account. We also see other terminology used for the same or similar concepts. Yet, the broad definition of prosumers used in this report captures all these specific concepts.

It is also important to note that there are four entities related to prosumption defined under the EU legislation: Renewable self-consumers and Renewable energy communities defined under the Renewable Energy Directive (RED II); and Citizen energy communities and Active customers defined under the Electricity Directive. These concepts are not mutually exclusive and overlap to varying degrees with our definition of prosumers. A review of these concepts is available in this study (EC, 2020b).

Table 3.1 Overview of prosumer attributes

Attribute	Explanation
Who can be a prosumer?	All types of entities can become prosumers: citizens (as individual prosumers or in collectives), companies or public institutions. The only requirement is that producing energy is not part of their main commercial activity. Therefore, large companies that produce energy, for example in industry, are not considered prosumers in this report. Energy communities and energy cooperatives are groups of citizens that jointly invest in renewable energy production or energy system services. Energy communities are entities that may have a local, regional or even national perspective. In many cases, however, they invest in RES products close to the homes of the members or shareholders of the community (Horstink et al., 2019).
What can prosumers do?	Prosumers are active participants in the energy system. In many cases, this means that they generate their own RES power or heat for self-consumption or are part of an energy cooperative that produces energy. However, prosumers do not have to produce the energy themselves; citizens who invest in RES or, for example, tenants who take part in a net metering system can also be considered prosumers (Fleischhacker et al., 2018). Prosumers can also play an active role in the energy system by storing energy, typically in times when they produce more than they consume or by providing demand flexibility.
Which technologies are suitable for prosumption?	Solar panels are the most common technology used by prosumers in Europe (Horstink et al., 2019), but prosumers can make use of numerous types of technologies to produce their energy, including wind and renewable heat technologies (EC, 2018). Other technologies suitable for prosumers include energy storage (such as batteries or heat storage), electric vehicles, heat pumps or electricity and district heating networks.
Who owns and operates the prosumption assets?	Prosumer projects can have different ownership structures. This is related to the type of entity that operates the project, which will define the ownership structures that are possible (Horstink et al., 2019). Individual house owners are usually the sole owner of their prosumer technology, but different ownership structures are possible for tenants and for energy communities, for example cooperative shares or equity shares.

Table 3.1 Overview of prosumer attributes (cont.)

Attribute	Explanation
How can prosumption be profitable?	In line with the definition of prosumers, selling energy or providing energy system services are not prosumers' main commercial activity. However, prosumer projects must be profitable (or at least cost neutral), otherwise most citizens will not consider engaging with them. The prosumer business model defines not only who bears the cost and risks, and who decides and benefits from the savings, but also the roles and relationships between the stakeholders involved, for example the prosumer and the relevant grid operators and energy companies, and perhaps a service provider that supports the project. Government policies, taxes and regulations can affect the business models that a prosumer may use and also their attractiveness (Brown et al., 2020). A positive business case will be a prerequisite for most stakeholders to engage in a project (Horstink et al., 2019). However, other motivations, such as a desire for autarchy or to contribute to the energy transition, are also possible.
Which legal forms are suitable for energy communities?	Some key legal issues that have to be considered are the type of equity that entails different forms of financing, voting rights, information rights, liabilities and risks, purpose of the entity such as social benefits, profit maximisation (see Lowitzsch, 2019).

3.1 The different forms of prosumption

Numerous combinations of these attributes and therefore numerous possible prosumer concepts are possible. The case studies described in Chapter 4 illustrate this range. In this report, we distinguish four different types of typical prosumer concepts to structure the various discussions. Some of these prosumer concepts are widespread, while others are still emerging. Structuring the four different types in this way is useful for the analysis, but it may be somewhat artificial, as hybrid forms of these concepts may and do occur.

3.1.1 Individual households

An individual household that has installed PV panels on the roof or on the balcony, possibly in combination with a battery to increase self-consumption (Figure 3.1).

A household with PV panels and a heat pump. The electricity from the PV system is used for the heat pump, which means that the household produces some of its own heat. A battery or heat storage can be used to increase the share of self-consumption further.

A household with a battery that offers grid-balancing services to grid operators or demand-side flexibility. This prosumption model is a key element in the Luče case study (Section 4.4).

A household with PV panels and an electric vehicle. The electricity from the PV system is used to charge the electric vehicle, which can also be used to offer grid-balancing services to grid operators.

A household becomes a member of an energy community or invests in a large energy-generating device (see energy communities and cooperatives). The Som Energía case study is an example of this model (Section 4.1).

A household participating in a network for energy services, for example by renting and using a battery for reserve provision.

Figure 3.1 Schematic diagram of a possible prosumer household

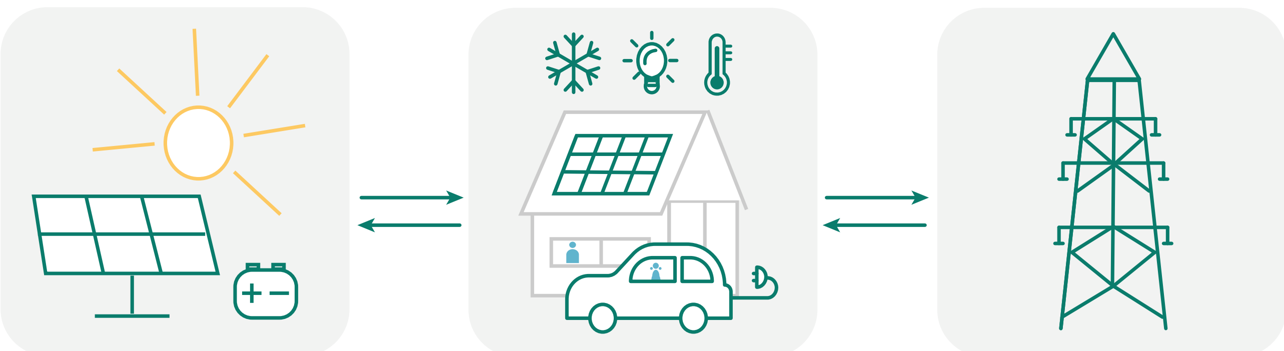


Figure 3.2 Schematic diagram of collective prosumers in one building

3.1.2 Collective prosumers in one building

An owners' association that owns a PV plant on the roof of an apartment complex (Figure 3.2). The apartment owners form an owners' association and contribute to the investment. Depending on the regulations in place, they may also be able to directly consume the power delivered by the plant.

Batteries, heat pumps and electric vehicles can also contribute to increased self-consumption and demand-side flexibility services.

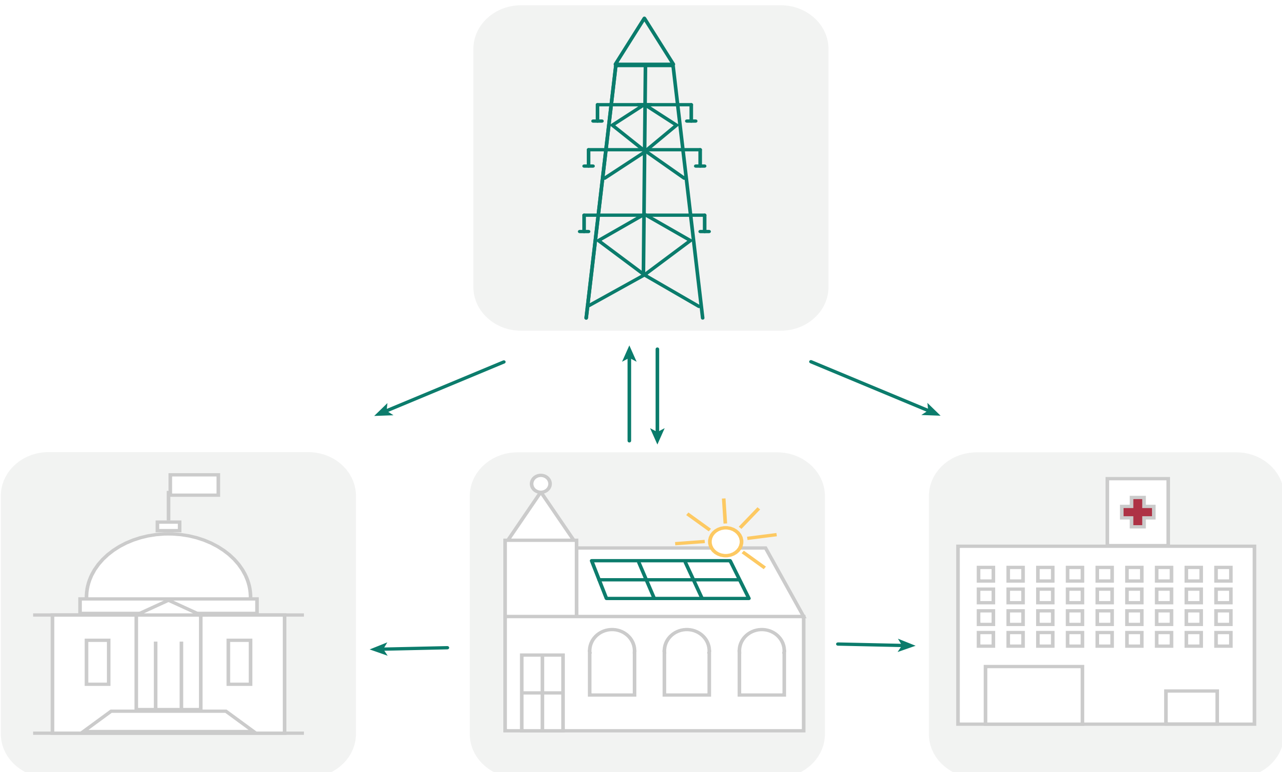
Tenants and owners of apartment buildings that have become prosumers can form their own in-house energy network to increase self-consumption (like the prosumers in the Schoonschip case study are doing; see Section 4.2).

3.1.3 SMEs and public institutions

An SME that owns a PV plant installed on the roof of its office building.

A public institution, such as a school or a government office, that owns a PV system installed on the roof of its building (Figure 3.3).

Figure 3.3 Schematic diagram of prosumption for public institutions



A network of public institutions where, for example, a school consumes the electricity produced by a PV plant located on the roof of a municipal swimming pool.

3.1.4 Energy communities and cooperatives

Energy communities are the most diverse group of prosumers. In principle, this group includes a variety of forms, ranging from very integrated energy neighbourhoods (such as Hvide Sande or Schoonschip) to national communities (as in the case of Som Energía). With regard to active customers, this category can also entail initiatives in which individuals participate in a company-led project (as in the case of Compile in Section 4.4).

The two main models for energy communities are:

- An energy community with members that pay contributions to the entity.
- An energy community with shareholders that own and control the entity.

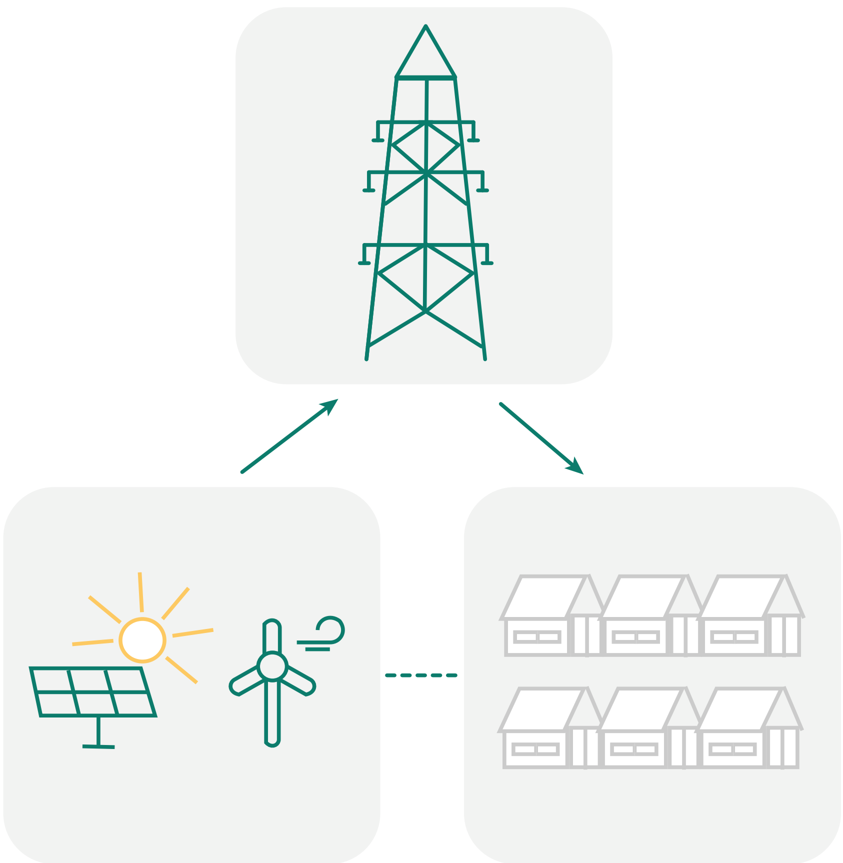
In both cases, the energy community invests in a type of RES, for example a wind turbine, a ground-mounted PV plant, a large battery or district heating (Figure 3.4).

3.2 Current state of prosumption in the EU

As the cost of RES production has decreased in recent years and many governments have promoted prosumption, for example through net metering systems or subsidies, the number of prosumers has increased in many EU countries. This is also driven by an increasing interest from citizens and businesses to contribute to the energy transition and reduce their personal impact on the climate (Horstink et al., 2019).

The total number of prosumers in the EU Member States and the EU as a whole is not known (Doračić et al., 2020) because of the lack of data and monitoring of prosumption. This has several causes: Member States have not been required to monitor prosumption, and many types of prosumption concepts use different sets of technologies and ownership structures. This makes it difficult to define homogeneous categories for EU-wide monitoring.

Figure 3.4 Schematic diagram of possible model for an energy community



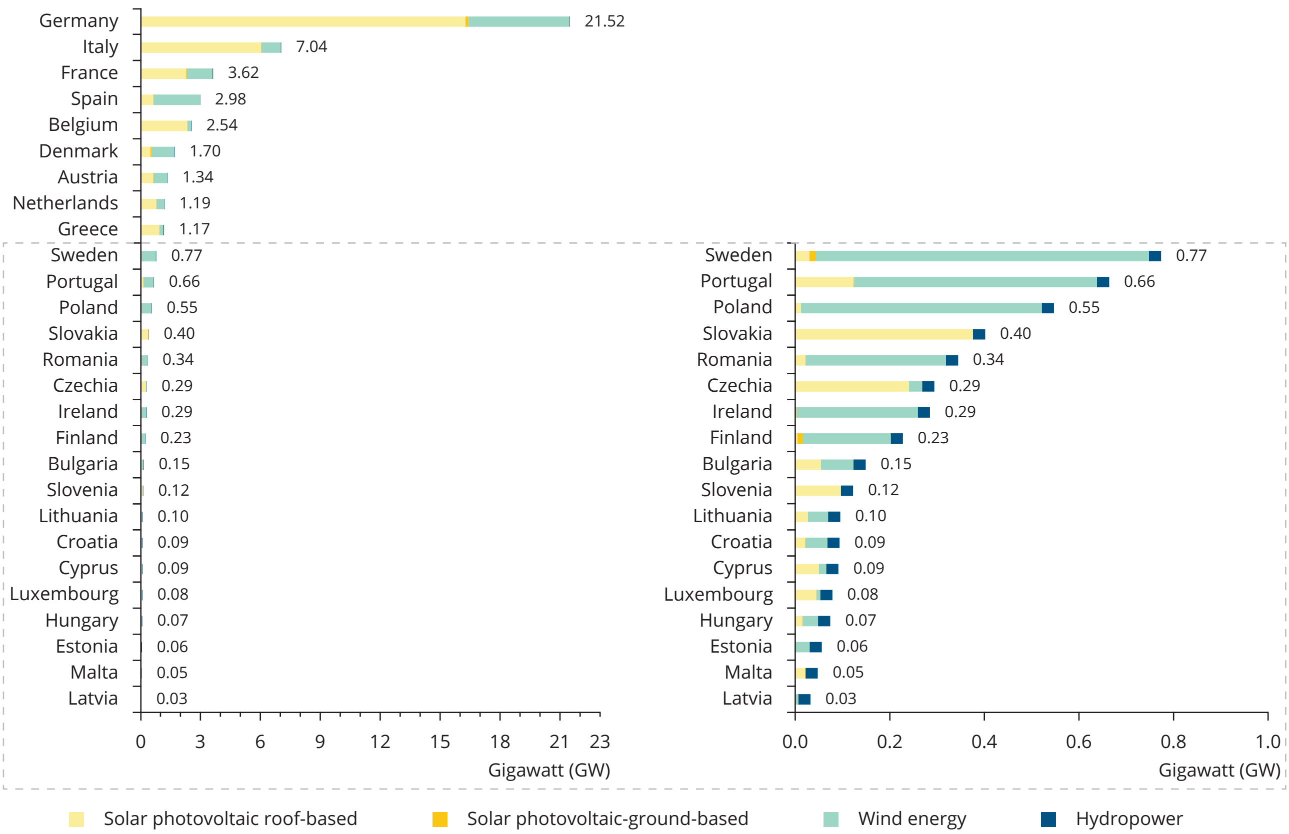
However, some numbers are available for specific technologies or individual Member States. These data indicate that the number of prosumers is increasing rapidly, at least in some countries. For example, the number of PV prosumers in the Netherlands has increased from less than 500,000 in 2015 to over 1 million in 2020, and the number of PV prosumers in Portugal has increased from 3,000 to over 30,000 in 2019 (PVP4Grid, 2020a). In Poland, the number of prosumers grew from 51,000 in 2018 to 847,000 in 2021, with an installed capacity of almost 6 GW (URE, 2022).

Very little is known about the number of energy cooperatives in the EU, but, to give an indication, REScoop, the European federation of citizen energy cooperatives, has a network of 1,900 European energy cooperatives, bringing together a total of 1,250,000 citizens (REScoop, 2022). In 2018, a study found that Germany had 824 active energy cooperatives, Austria had 286 and Denmark 186 (Wierling et al., 2018). Interestingly, the number of cooperatives in Denmark decreased significantly between 2000 and 2018, as support policies were phased out, while the number increased rapidly in Germany between 2008 and 2018 due to the introduction of new support policies (Wierling et al., 2018). The Netherlands has over 600 energy communities or cooperatives with almost 100,000 participants (Hier opgewekt, 2021).

Figure 3.5 shows an estimation of the installed capacity for electricity production by prosumers (both individual and collective) in 2015 (CE Delft, 2021) ([4]). The figure shows that most of the electricity produced by prosumers comes from PV panels on roofs, followed by wind turbines. The contribution of ground-based PV installations and hydro-energy is marginal.

As Figure 3.5 indicates, in 2015, Germany had the highest amount of installed capacity linked to prosumers, followed by Italy, Spain, France, Belgium and Denmark (CE Delft, 2021). This is partly influenced by the size of the country and its climate (e.g. average hours of sun per day), but it is also influenced by policies that stimulate prosumption in these countries (see Section 7.2 for some examples). The production of electricity by prosumers in eastern Europe is still relatively small due to a historical lack of stimulating policies and comparatively low electricity prices, although this is changing rapidly in some countries (e.g. Poland).

Figure 3.5 Installed capacity for electricity production by prosumers in the EU in 2015



Note: Because of the rapid developments in prosumption and renewable energy technologies in recent years, these numbers have probably changed since 2015. However, EU-wide numbers for more recent years are unavailable.

Source: CE Delft (2021).

([4]) These data include a wide range of prosumer types and prosumption technologies. Individual prosumers are considered to be households, and collectives range from neighbourhood level to city-wide energy communities. The tertiary sector (services) is also included as a potential prosumer. Decentralised electricity production owned by commercial parties is not included in these data.

The data presented in this section are based on estimates and do not cover all types of prosumption, highlighting the need for better monitoring and reporting to quantify the full impact of prosumption on the energy system. The Regulation on the Governance of the Energy Union and Climate Action (EU, 2018a) is a step in the right direction. From 2023, Member States are required to report on the renewable energy produced in buildings, as well as by energy communities and cities (Annex IX (k)(l)). Details of the specific metrics to be reported are currently being developed into an Implementing Act.

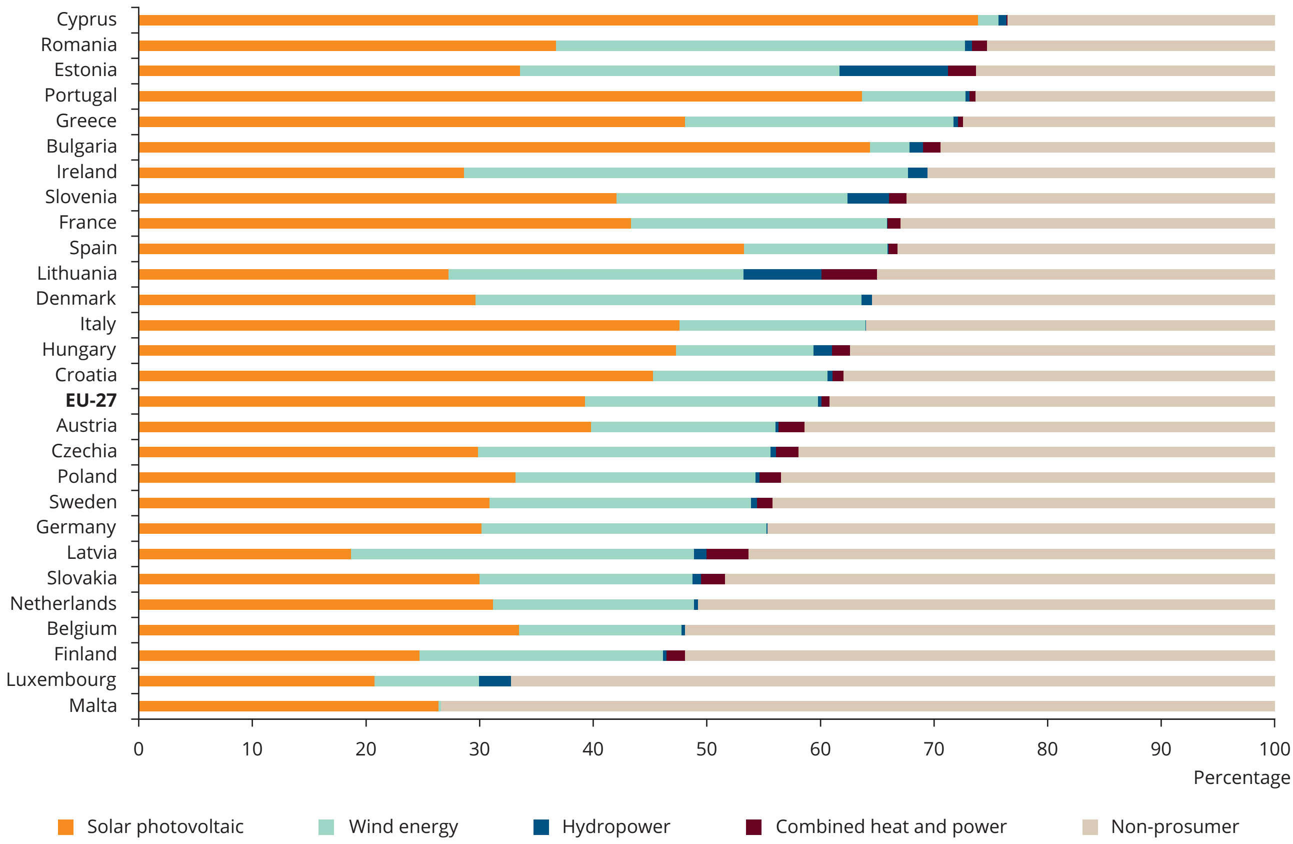
3.3 The technical potential of prosumption in the EU

Studies indicate that the potential for prosumption is enormous. It was estimated that almost a quarter of EU electricity consumption (680 TWh) could be generated from rooftop solar photovoltaic systems alone, based on existing building stock (Bódis et al., 2019).

From a technical point of view, it is possible for almost every citizen in the EU to become a prosumer, either individually or in a collective (Doračić et al., 2020) ([5]). One could put solar panels on top of many buildings and there are plenty of other options, depending on where one lives. This may require local or regional expansion of the electricity grid or the development of heat infrastructure, but, from a technical perspective, this potential is achievable (Doračić et al., 2020).

Figure 3.6 shows the technical potential for electricity production ([6]) by prosumers compared with the total electricity demand for all EU Member States, as calculated in CE Delft (2021). Their report found that prosumers can provide 30-70% of the total electricity depending on the Member State, solar and wind being the technologies with the highest potential. The same report found that prosumers could cover the total heating demand of households in 2050 with a variable mix of electricity, biomass, solar heat and district heating, depending on the country.

Figure 3.6 Technical potential electricity production by prosumers in 2050, relative to the total electricity demand in the EU



Note: The potential for CHP (combined heat and power) in these data refers to electricity production by combustion of biogas in CHP installations. The contribution of this technology to the technical potential is low in all EU Member States.

Source: CE Delft (2021).

([5]) The reports by Doračić et al. (2020) and CE Delft (2021) use a similar definition for prosumers as this report. Producing renewable energy as a commercial activity is not considered prosumption.

([6]) Corresponds to the electricity produced if all available space and resources were used by prosumers to produce their own energy with RESs. The economic feasibility of the renewable energy technologies is not considered.

The technical potential for electricity production and the choice of technology depends on different factors (Doračić et al., 2020). The most important are:

Climate. The potential for PV installations is higher in southern European countries, which have more hours of sun during the year than northern European countries.

Urbanisation. Crowded regions have less space for RES generation on land, for example ground-mounted PV plants or wind turbines, than rural areas.

Geological properties. Geology affects the potential for RES production by prosumers. This mainly applies to hydro-energy, which is possible in only very specific locations.

Available area. The available rooftop area restricts the potential for rooftop PV panels, and available land restricts the potential for wind turbines and solar farms.

It should be noted, however, that the figures above consider only the technical feasibility under ideal circumstances. While there is vast potential, it is still not known which part of it is also cost-effective. Moreover, it must be debated whether or not such a scenario is indeed desirable and under which circumstances. The realistic potential, which takes economic and social factors into account, may be substantially lower than the technical potential. So far, however, a thorough assessment of what would be a realistic scenario has not been carried out.

4
Prosumers in Europe: four illustrative case studies

Prosumption in Europe can take many different forms, depending on the scale, the technologies used, the organisational structure and the business model. There are many successful and interesting local and regional prosumer initiatives throughout Europe. Here we introduce four of them to illustrate the wide range of prosumer activities to which citizens contribute.

Many readers will have come across individual prosumers, energy cooperatives or other types of prosumption in their neighbourhood or region.

In the following sections, we describe four case studies of energy communities from different countries in Europe (see Table 4.1). These were selected to illustrate best practice in different regions and showcase differences in organisational structure, technologies, impacts, business models and ownership. They show that, where the local circumstances and the policy framework provide the right conditions for prosumer projects, enthusiastic individuals and communities can develop successful projects together. Favourable financial conditions are key drivers in many cases, but other considerations can also play a role. The projects have impacts on many different levels: reducing greenhouse gas (GHG) emissions, generating energy from renewable sources, bringing social benefits, improving security of supply, etc. These case studies are also referred to in other chapters of the report when discussing the various topics that they cover.

These projects have been implemented in specific circumstances and may not be attractive prosumption options everywhere, but their main features and principles can be scaled and applied wherever similar favourable conditions exist. It should be noted, however, that this selection is not intended to provide a comprehensive overview of prosumer project types, nor does it suggest that these types of projects are preferred to others.

Table 4.1 Overview of selected energy communities in four different EU countries

Name	Country	Main organisational characteristics	Main technical characteristics
Som Energía, S. Coop.	Spain	Non-profit consumer cooperative formed by volunteer members in 2010, which had grown to more than 77,000 members in 2021.	14 photovoltaic (PV) plants, 1 hydropower plant and 1 biogas plant. Production from own plants in 2021: 18.8GWh. Energy sold in 2021: 430GWh.
Schoonschip	Netherlands	A local collective of 47 floating households in Amsterdam.	Heat pumps, PV panels, solar thermal collectors, battery and thermal storage; a private smart grid with one central connection to the public grid.
Hvide Sande Fjernvarme	Denmark	An energy company owned by consumers, founded in 1963. The company operates a district heating network.	District heating with 6MW electric boiler, 9,576m^2 solar thermal collectors, 3 wind turbines (3MW each). Heat pump for district heating with heating capacity of 4.7MW.
Compile — Luče	Slovenia	Smart load management with option of self-sufficiency in a remote village with frequent power supply disruptions.	Community battery (150kW/333kWh), 5 household batteries, PV installations and an electric vehicle charging point.

4.1 Som Energía: an energy community with more than 77,000 members in Spain

4.1.1 Prosumption concept

Som Energía is a renewable energy community organised in local groups across Spain. The cooperative has more than 77,000 members who take part in the energy transition in various ways.

(Som Energía, 2022)

4.1.2 Membership and renewable energy source supply

Som Energía members pay an upfront fee of EUR 100 and sign a contract that guarantees the supply of 100% renewable electricity. Som Energía supplies the power from its own renewable energy source (RES) plants complemented by wholesale market purchases and green certificates from mostly Spanish RESs to its members. Excess electricity from Som Energía plants is sold to the market. The required upfront contribution is refundable when a member cancels their membership. Further investments from members are possible but voluntary. Each year, the shareholders' meeting decides how to use the profits and how much interest members receive on invested capital, following the one person, one vote principle.

(FLEXCoop, 2020; Som Energía, 2021a)

4.1.3 Collective investments in renewable energy sources

Som Energía itself generates 4.4% of the RES it markets to members, amounting to 18,800 MWh in 2021. The cooperative does not operate electricity networks and is not responsible for balancing the grid ([7]). Its members keep paying other price components such as taxes, levies and grid access fees. Most of Som Energía's RESs do not receive subsidies. Since 2014, an auctioned premium tariff compensates the producers of renewable electricity generation in Spain, which is financed by the national budget. This market-oriented support mechanism is not aimed at individuals participating in auctions and the cooperative has better resources for this administrative procedure. However, the offer for a new PV plant of around 3MW from Som Energía in an auction in December 2020 was not successful, since larger commercial utilities have underbid the cooperative.

(Som Energía, 2018, 2021b, 2022; Res Legal Europe, 2019; Banal Estanol, 2021)

4.1.4 Crowd finance model for new investments

Som Energía uses a crowd funding model called 'Generation kWh' to raise investment capital for new RES projects. All members can participate by purchasing shares. For each EUR 100, investors get a number of kilowatt-hours at the cost of generation every year, for 25 years. Taxes, grid fees, etc., are paid for, and other fixed costs such as maintenance, rent and insurance are covered by, long-term contracts between the cooperative and the investor in the crowd finance scheme. The capital invested will be returned to the investor after 25 years. Unlike general investments, money deposits in the 'Generation kWh' crowd finance model do not receive interest payments but cheaper electricity instead. Som Energía has developed a high level of trust among its members, which they consider their strongest asset and results in quick acquisition of capital to finance new projects.

(REScoop MECISE, 2019; Caramizaru and Uihlein, 2020; Banal Estanol, 2021; Generation kWh, 2021)

4.1.5 Collective purchase of photovoltaic modules for its members

Members who want to install their own individual PV (plus battery) rooftop installation benefit from local collective purchase schemes, resulting in reduced prices because of the increased bargaining power of a larger purchase. Local groups of experts offer turnkey solutions for PV installations to simplify the process. The average installed capacity is $3kW_p$ (kilowatt peak) and 10% of prosumers are also installing batteries. The cooperative collectively organises the process of distributing excess electricity from members' plants to supply other members via the public grid or selling it on the wholesale market. Members are compensated for the excess electricity by net-balancing or by a tariff on the grid injected electricity (19 cents/kWh in June 2022).

(Som Energía, 2021c, 2022)

([7]) The electricity system needs to be balanced (generation=consumption) at all times. Hence, the transmission grid operators coordinate such balancing.

4.1.6 *Local engagement, energy efficiency and energy poverty*

Membership of Som Energía gives access to a network of experts who voluntarily guide their fellow members towards more efficient and responsible use of energy and thus savings on their energy bills. Motivated members can join these groups and become active, for example through organising and attending conferences, debates and meetings across the country. Members can share the membership fee with five other participants without further costs. This particularly benefits people on low incomes, when Som Energía, together with cooperating municipalities, covers the energy costs of struggling members.

(Pellicer-Sifres et al., 2018; Som Energía, 2022)

4.1.7 *Barriers, challenges, drivers and enabling factors*

Som Energía is growing faster than the supply capacity can be expanded. This raises the question of whether Som Energía should support only large RES projects or stop the growth of its membership base. The fact that Som Energía is active across the country is burdensome, because each region may differ in the pace of progress and required investments. Democratic decision-making in the cooperative may not be feasible with a much larger membership.

(Pellicer-Sifres et al., 2018)

4.1.8 *Scalability and innovation potential*

Som Energía has been growing rapidly in recent years. Between 2018 and 2021, the cooperative nearly doubled its sales of electricity. Through the financing scheme 'Generation kWh', the cooperative was able to undertake projects with financial conditions that would not be profitable for traditional business but are sufficient for the community. As well as installing its own plants, Som Energía aims to promote other local energy cooperatives by providing advice and becoming stakeholders, for example with the energy cooperative Energética. With increasing technological and regulatory opportunities to manage the energy demand of its members, Som Energía may turn into a service provider offering flexibility to other parties connected to the grid. It may increase its supply to the grid when demand is high or redistribute power among its members when the demand on the grid is low. In addition, Som Energía may also use the flexibility to provide balancing services.

(REScoop MECISE consortium, 2018; FLEXCoop, 2020; Som Energía, 2020; Banal Estanol, 2021)

4.1.9 *Key figures*

Coverage and size:

- across Spain
- 73,000 individual members
- 2,700 businesses and cooperatives
- 613 foundations and associations
- more than 100 public administrations
- organised in 57 local groups.

Renewable energy generation in 2021:

- 429,985MWh sold electricity
- 18,823MWh total generated electricity
  - 1,249MWh hydro
  - 2,186MWh biogas
  - 15,388MWh PV plants.

Staff: 105 employees

4.2 Schoonschip: a prosumer collective in the Netherlands

4.2.1 *Introduction*

The 'Schoonschippers' (or 'Fair Skippers') is a local collective private undertaking, which means that one or more private individuals acquire an area for development and determine what they would like to build and which parties they work with. The project, situated in Amsterdam, claims to be the most sustainable floating neighbourhood in Europe. Forty-six families live on 'woonboten', a Dutch concept in which people permanently live in specially designed arks. Schoonschip has a private smart grid, which enables households to optimise energy use among themselves, with a smart community platform for managing the network. Schoonschip also aims to improve water ecology and provide a place to enjoy nature. The households share electric cars, bicycles and cargo bikes (Schoonschip, 2021a).

4.2.2 Prosumer concept and organisation

The families living in Schoonschip form an active community. Although the organisation functions as a collective private undertaking, in reality the participants are all independent private developers of their own ark. A cooperative was formed to develop the jetty and smart grid. The cooperative has a board, which managed all the personal preferences and environmental demands.

In 2019, a new private foundation named 'Pioneer Vessel' was started by the board. This enables the testing of new concepts and a car-sharing initiative to be set up. It makes sharing of infrastructure possible and organises all activities in communal areas, such as tours for guests. Each member of the foundation pays a small annual contribution to take part in these activities (Schoonschip, 2021b).

The collective assets are also collectively owned, with each participant required to invest EUR 70,000 to cover the costs of the jetty, electricity and plumbing, compensation of the board, the project costs and the costs of the necessary permits ([8]). Overall, the costs of the project were higher than the average costs of new-build homes. Although the cost of building the arks was comparable to building similar-sized sustainable housing on land, there were additional costs for the communal jetty, utilities and the central shared area, as well as costs associated with the complex legal situation, which required a lot of expert advice (Schoonschip, 2021c).

4.2.3 Energy system effects

Local PV plants feed electricity into the smart grid, which allows sharing, for example if a household is on holiday. Several home batteries offer additional flexibility. The community aims to balance power supply and demand within its local power grid and has only one connection to the city grid.

Energy exchange between Schoonschip and the city grid system is much lower than for other prosumers that individually own solar panels and do not share their energy with their neighbours. Most energy is used and/or stored in the Schoonschip network itself, reducing the strain on the public grid (Schoonschip, 2021d).

4.2.4 Support schemes and policies

The initial feasibility study was possible thanks to local support at the municipality level (Schoonschip, 2021a). The province also provided a loan (EUR 276,000) during the start-up phase, which is to be repaid by the participants over time. Additional funding was provided by a Dutch foundation (Stichting DOEN) to develop a knowledge exchange platform for similar projects inside and outside the Netherlands (Schoonschip, 2018).

In the Netherlands, citizens are not allowed to own and operate their own grid. However, the competent authorities have made an exemption because they want to enable communities to have their own sustainable local energy networks to stimulate innovation. It is expected that the regulations will be changed and that this type of grid ownership will be permitted in the future, rendering the exemption unnecessary (Schoonschip, 2021b).

4.2.5 Social and socio-economic effects

Households' energy costs are expected to be very low or zero, since energy is produced, stored and used locally and the project aims be energy neutral over the year. Water-saving measures bring additional cost reductions.

The community aims to foster social cohesion between members. The collective has a number of shared facilities, and it also promotes sharing of private items, such as tools, and collective food purchases from a local farmer. The community also organises activities, including tours for guests.

4.2.6 Key figures

Size:

- 30 arks
- 46 families
- 105 inhabitants.

Energy:

- 500 solar panels
- 30 heat pumps
- several batteries.

Ecology:

- floating gardens.

([8]) To put this number into perspective, the average energy expenditure in the Netherlands is approximately EUR 1,500 per household per year (CBS, 2021).

4.3 Hvide Sande Fjernvarme: consumer-owned district heating in Denmark

4.3.1 Prosumption concept

Hvide Sande Fjernvarme AmbA is one of many consumer-owned energy companies outside large cities in Denmark. The Danish District Heating Association, a stakeholder group promoting collective prosumption models in the heating sector, initiated the company's founding which took place in 1963. Hvide Sande Fjernvarme owns and operates a district heating network on the Danish west coast. As well as the network infrastructure (pipes, control equipment, etc.), it owns two gas-fired combined heat and power (CHP) units, two gas boilers and RES heat generation technologies, including solar thermal collectors, a large-scale heat pump ([9]) and an electric boiler. The energy community also owns three local wind turbines. The company is managed by a board of five people, who are elected at an annual general meeting for a 2-year term. This way, all end users influence the selection of suppliers and other decisions. The company employs three people for its technical operation and office and service support.

(Blanco et al., 2018; Lowitzsch, 2019; Dansk Fjernvarme, 2021; Hvide Sande Fjernvarme, 2021)

4.3.2 Social and socio-economic effects

In Denmark, district heating grids are subject to a non-profit rule in accordance with the Heat Supply Act. Yet, the Danish regulations allow the inclusion of all necessary costs in the price of heating. These frameworks are especially favourable for energy infrastructure, which is collectively owned by the connected consumers, such as the district heating grid in Hvide Sande. When sharing the cost of one joint heating system ([10]), consumers profit from low energy prices and this effect can increase as the number of connected consumers increases (although it will depend on the structure of the local demand for heating and distance between consumers, etc.). This structure provides a stable ownership environment for consumers in the long term (Gorroño-Albizu et al., 2019).

4.3.3 Energy system effects

In addition to direct RES heat generation in solar collectors, the energy community in Hvide Sande deployed an electric boiler and a large-scale heat pump ([11]). Both use renewable electricity, for example from the community-owned wind turbines, to generate heat.

Using electricity to generate heat with heat pumps ([12]) is considered necessary to improve the integration of variable renewable electricity generation into the energy system. It can help compensate for shortfalls in wind and solar power. While heat pumps are increasingly used at household level, large-scale heat pumps are still used relatively rarely and the community of Hvide Sande is among the pioneers of this technology.

(David et al., 2017; Gorroño-Albizu et al., 2019; Gorroño-Albizu, 2020)

4.3.4 Environmental aspects and resource efficiency

Heat pumps are a very efficient technology. The electric boiler used in Hvide Sande is a very simple and cheap technology, which provides additional flexibility for peak load and times when high levels of renewable energy are generated. Moreover, the heat grid itself provides storage capacity, and additional heat storage (e.g. hot water tanks) can be easily added at low cost. This is an additional source of flexibility. The whole system can thus contribute to integrating variable renewables into the electricity grid and making efficient use of the electricity generated.

4.3.5 Promotion of collectively owned district heating in Denmark

Power plants generating RES electricity, such as wind turbines, PV installations and hydropower and also biofuels used for heat generation, enjoy tax exemptions in Denmark. Small-scale CHP installations have received subsidies in the past, but support was terminated in 2018 for those plants using fossil fuels. Thus, technologies in district heating are

([9]) The investment in the large-scale heat-pump was around EUR 0.4 million (DKK 30 million) and it started operating at the end of 2020. This technology allows the exploitation of heat from the air with an annual coefficient of performance (COP) factor of 3.5.

([10]) From a technical point of view, one large heating system can also be a large network with several sub-networks that is owned by one entity, i.e. an energy community. The owner allocates the costs of the entire network, i.e. the costs of the various sub-networks, to all connected customers, resulting in the costs being shared among all consumers.

([11]) Heat pumps extract heat from environmental heat sources, e.g. air, rivers, (surface) geothermal energy or anthropogenic heat sources, e.g. waste water or industrial processes, using renewable electricity from wind and solar PV plants. This sector-coupling technology is a very sustainable and efficient way of generating heat. Depending on the temperature and availability of the heat source, the amount of heat energy generated is three to five times higher than the electrical energy used in a heat pump. Integrating large-scale heat pumps in district heating networks enables heat to be extracted centrally from heat sources that households usually do not have access to, e.g. geothermal sources or rivers.

([12]) Using electricity in other energy sectors (i.e. heating and cooling or transport) is called 'sector coupling' or an 'integrated energy system'. Future energy scenarios see this as an important element to reduce the energy sector's CO_2 emissions and integrate variable RES power generation into the energy mix. customers, resulting in the costs being shared among all consumers.

shifting towards direct electrification and biomass. In the case of Hvide Sande, full levies and fees, for example network charges, need to be paid for self-consumed electricity if the public grid is used. Thus, Hvide Sande often sells its generated electricity on the general electricity market, as well as buying from it. Municipalities can provide loan guarantees to district heating communities to reduce their interest rates. Thus, the consumer finally profits from dividing the cost of the asset among all participants, resulting in lower energy costs than with individual heating solutions.

(Blanco et al., 2018; Gorroño-Albizu et al., 2019; Lowitzsch, 2019).

4.3.6 Barriers, challenges, drivers and enabling factors

The transition to a sustainable heating and cooling sector is very challenging; for example, the interaction between the renovation of houses and their demand for heating on the one side and the planning of a heating grid on the other side makes this complicated. Another challenge is to motivate many customers to participate in district heating to reduce the overall cost to individuals. In Hvide Sande, the Danish District Heating Association was involved, motivating inhabitants to join the district heating project. The association also took over the planning of the district heating network.

(Gorroño-Albizu et al., 2019; Lowitzsch, 2019)

4.3.7 Scalability and innovation potential

Theoretically, in all areas with a sufficiently high demand for heating (and thus population density), a district heating grid could be deployed. Many long-term studies on decarbonised energy systems highlight the need for a broad deployment of district heating. Heating grids in combination with heat storage can provide considerable flexibility and enable the expansion of wind and solar power. The structure of community-owned district heating has the potential to harness the local development of district heating networks by involving consumers.

(David et al., 2017; Fraunhofer ISI, Consentec, ifeu, 2017; Paardekooper et al., 2018)

4.3.8 Key figures

Size:

- 1,632 customers
- 27,728 MWh sales of heat
- 19,512 MWh sales of electricity.

Installed technology:

- Solar thermal collectors (9,576m^2)
- Heat pump (4.65MW)
- Electric boiler (6MW)
- 3 Wind turbines
- 2 gas-fired CHP units (each 3.6MW electricity and 4.6MW heat)
- 2 gas boilers (10.3MW and 3.7MW).

4.4 Compile — Luče: intelligent management of demand and supply in Slovenia

4.4.1 Prosumption concept

This is a company-led prosumer project in the remote Slovenian village of Luče, which is in the mountainous upper valley in Štajerska. The people of Luče regularly suffered electricity outages, because of an unstable connection to the public grid. With support from the municipality, a local energy provider, Biomasa, and one of the largest Slovenian energy companies, Petrol, initiated the pilot project Compile. By promoting intelligent management of power demand and supply, the project aims to improve energy security and explore new ways of providing ancillary services to the distribution system operator (DSO) and the transmission system operator (TSO) with fair remuneration of all involved. The project received local support in the village because it promised to be a step towards energy independence and energy security benefits local agricultural businesses.

The two companies, Petrol and Biomasa, invested in RES plants, domestic and communal battery storage, and electric vehicle charging stations, combined with intelligent energy management tools. Petrol acts as an aggregator and supplier and offers contracts with net metering schemes for individual end users. Petrol deploys technology to manage local grid balancing within and between connected households. Citizens who wish to participate must sign an electricity contract with Petrol and can choose to co-finance the installations.

Unlike the other case studies, Compile is driven by private corporations rather than citizens. However, it offers the opportunity for consumers to participate more actively in the energy system than in traditional provider-consumer relationships. While aiming to implement a community structure to drive local engagement, the Compile project does not have a distinctive legal structure.

(Artač, 2019; Compile, 2020a, 2021)

4.4.2 *Participation of stakeholders and community benefits*

In 2020, only a small part of the village participated in the project because the regulations only permit energy communities sharing one low-voltage transformer. Most PV systems are installed on municipality buildings. Hence, the project was only accessible to households that share the same low-voltage transformer with one of these buildings.

The project information states that electricity sharing among different members via a virtual community platform should become possible. A metering system is in place that incentivises households to consume power when it is produced locally. However, the energy-sharing scheme will only begin as a pilot when a regulation exception allowing test sharing of energy between households takes effect.

Together with local initiators and leading figures, Compile also organises workshops to increase the number of participants in the project, learn about citizens' needs and assist them in deploying PV panels, batteries and other technologies (Compile, 2020a,b).

4.4.3 *Energy system effects*

The combination of decentralised RES electricity generation and the opportunity to temporarily store electricity in central and decentralised batteries enable Luče to switch into a self-sufficient energy supply mode when power outages occur. The energy management system either curtails the energy supplied by household solar panels or supports the grid with voltage when necessary and, hence, helps the DSO to balance the grid. Excess power, which cannot be stored in the local system, can be sold on the electricity markets or used by the TSO.

(Artač, 2019; Compile, 2020a,b)

4.4.4 *Support schemes and policies*

During the development of this project, RES-producing communities could not be part of a support scheme in Slovenia. However, under a new regulatory exemption, consumers participating in the community may enjoy a grid fee reduction of about 20%.

(Artač, 2019; Compile, 2020a)

4.4.5 *Barriers and challenges*

Since Slovenian energy law forbids the exchange of energy across households that are not connected to the same low-voltage transformer, the integration of the entire village of Luče would be difficult. Under current regulations, only many small energy communities can be established. Full integration thus requires regulatory change.

Luče's low-voltage electricity grid is weak and unstable, which is impeding the integration of significant RES capacity. In addition, transformer stations must be modified and technical permits obtained to use larger, centrally located batteries to switch to operation in island mode (i.e. temporarily isolated from the main grid). Microgrid operators also face high regulatory complexity with respect to their responsibilities in grid management and the interaction with the local DSO.

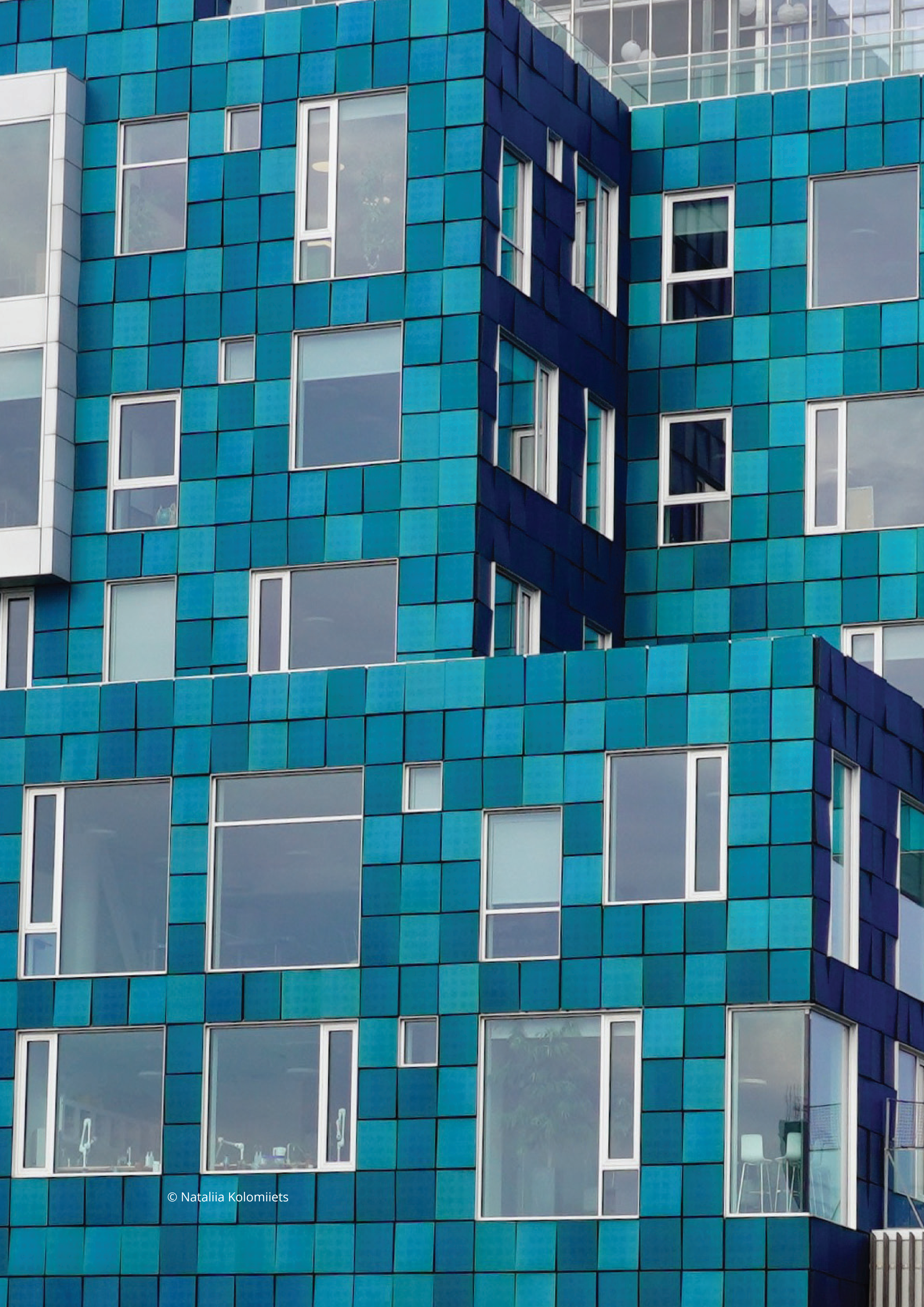
(Compile, 2019, 2021)

4.4.6 *Key figures*

Facilities additionally implemented through the Compile project:

- installation of 102kW PV panels
- installation of community battery (150kW/333kWh)
- installation of five household batteries
- installation of community electric vehicle charging point
- integration of a home energy management system (HomeRule) operated by the energy provider, Petrol
- integration of microgrid control (GridRule) with functionalities for data management, machine learning and forecasting based on a Petrol commercial solution
- provision of emergency supply with a community battery to mobile communications to enhance community safety during crises (island mode).

Total electricity generated between October 2019 and October 2020**:** 10,253kWh.



5
Key aspects affecting the choice of prosumption model

Individuals who want to become prosumers can start by assessing which aspects of prosumption could be attractive for their houses, buildings or neighbourhoods. This involves gathering information on the relevant technologies, costs and benefits, regulations and available support schemes. They can find out whether collective energy initiatives already exist in their community or who they might want to join forces with to initiate a collective. National, regional and local authorities can support these initiatives and developments.

The previous chapters have introduced the different forms of prosumption and their benefits and challenges. But what form of prosumption fits best for citizens and small and medium-sized enterprises (SMEs) if they actually want to become prosumers? The key aspects to be considered are described in the following sections. However, as the individual circumstances and opportunities vary greatly, and the concrete regulations and framework conditions differ substantially between Member States, we can present only the general aspects, without going into specifics for each country.

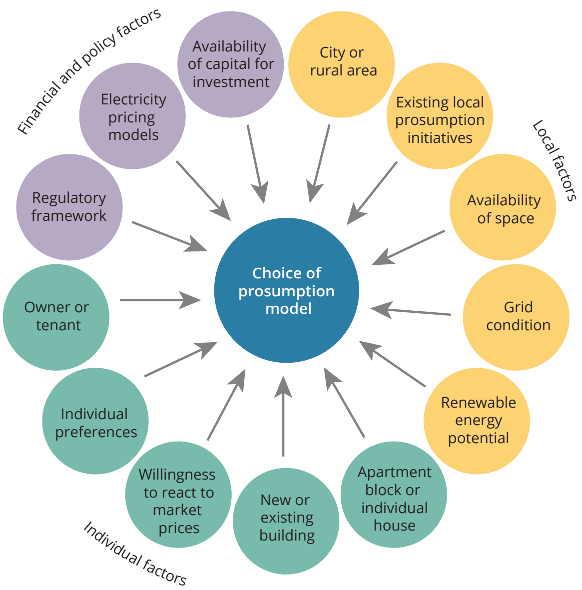
5.1 Opportunities

Many different aspects determine the possibilities of becoming prosumers and the most appropriate type of prosumption. This may depend on the type of dwelling and neighbourhood where a potential prosumer lives, the geographical and climatic characteristics, the financial considerations, neighbours' enthusiasm for participating, etc. (see Figure 5.1). While a homeowner can invest in their own photovoltaic (PV) rooftop system, a person renting an apartment can become active in an energy community. Local energy communities may already exist or may have to be established; alternatively supra-regional energy communities offer memberships (see Section 4.1, Som Energía case study). When cities plan new neighbourhoods, future residents may become active in planning the whole energy infrastructure. Local energy communities are often a good starting point for gathering information, since they have knowledge and networks at regional levels that can identify investment opportunities.

Opportunities also depend on the regulatory framework, for example the existence of a net metering scheme or a support scheme for collective prosumption (see the example of Greece in Section 7.2). These regulations differ substantially between countries and regions.

Thus, not all individuals can access all types of prosumption but many can choose between several possibilities. Figure 5.1 shows some of the most important factors determining the type of prosumption suitable for individuals.

Figure 5.1 Factors determining the choice of prosumption model



5.2 Costs and benefits

When choosing the most attractive type of prosumption for a given situation, a potential prosumer needs to carefully assess the costs and benefits of such an engagement. For many, this will, first of all, concern the financial cost and benefits. Individuals need to consider their financial situation:

- Is it possible to make the required investments?
- When will my invested capital be repaid?
- Are the financial risks acceptable or not?

The cost and benefits of a prosumer project will vary. For example, installing a PV rooftop plant requires an upfront investment but also enables savings in electricity costs to be achieved by reducing electricity consumed from the grid. Selling excess energy into the grid may be a source of revenue for prosumers, but the price variations during the day and across seasons should be considered. For example, a solar prosumer without batteries may sell excess electricity during the middle parts of the day, when residential consumption is low, and hence receive a lower payment per kilowatt-hour than at peak times. In contrast, they may purchase electricity from the grid in the evening, when the sun does not shine but demand is high and pay a higher price. The potential impacts of grid tariffs and fees should also be assessed. Participation in an energy community, on the other hand, may be realised by acquiring a share, or may involve an annual membership fee. Installing a collective heating grid in a specific location (like the Hvide Sande case study in Section 4.3) requires an initial investment but this can be shared between the group members, for example based on their possibilities and wishes.

If one prosumption option requires an upfront investment, a financial assessment involves first taking all the costs that will be incurred (installation and maintenance cost, interest on loans, etc.) into account. By combining these findings with the estimated lifetime of the installation, the annual cost of the investments can be calculated. An assessment of the financial benefits then involves estimating the cost savings resulting from the project, for example reduced energy bills and revenue from exporting electricity to the grid. To consider alternative investment options for the capital provided, the financial feasibility calculations should consider average interest and inflation rates as discount factors.

In addition to the financial aspects, other costs and benefits can be considered, such as the contribution to the energy transition, the lower CO_2 footprint of the household or benefits in terms of security of energy supply. Furthermore, costs and benefits do not occur only at the individual level but also at the community or societal level. Such wider effects might also be included in the selection process.

5.3 Project scale and ownership

Another consideration is whether an interested individual would be content with a small-scale project, for example one affecting only their own household's energy provision, or whether they would rather aim for a level of engagement with a wider system impact. This also relates to the key question of ownership and influence in decision-making. Does the individual prefer to own the prosumption asset individually or collectively in an energy community, or do they prefer to be an active energy citizen without owning an asset (e.g. by renting a battery or forming part of an energy collective)?

Social considerations can also become relevant here. Participating in a local energy community can increase the sense of community and personal interactions in a neighbourhood, which is also often appreciated by the participants (Horstink et al., 2019) (see the Som Energía case study, Section 4.1).

Larger-scale projects typically achieve more impact per euro invested. A rooftop PV plant can directly contribute to reducing CO_2 emissions, but investing the same amount in a bigger wind plant by participating in an energy community probably has a bigger effect on decarbonisation for the same cost. However, not every homeowner would like to invest in an energy community, but they might be willing to install an individual PV rooftop plant. Renting a battery and participating in a group providing energy storage services to the grid can contribute to the integration of renewables into the electricity system and possibly reduce the system costs of flexibility. A collective heating grid might reduce and stabilise the costs of heating and cooling in the area, improve the social cohesion of the neighbourhood and potentially increase the value of houses in the area.

5.4 National and local policies

Throughout Europe, the attractiveness of certain forms of prosumption, including costs and benefits, are influenced by the regulatory framework. For example, support schemes for prosumers, or renewable energy initiatives in general, can significantly contribute to reducing the payback times of investments. However, complex and long administrative procedures to access grants or obtain permissions may discourage individuals and SMEs from prosumption. These framework conditions differ substantially between countries and even regions (see Chapter 7).

5.5 What prosumption type fits best?

In terms of individual households and SMEs wishing to become active players in the energy system, one needs to differentiate mainly between owners and tenants. While both can participate in energy communities or energy collectives, only owners can invest in their own electricity generation plant or battery (unless the proprietor allows the tenant to use the roof or another part of the building for energy generation). For tenants with a balcony, depending on the national regulations, it may be possible to use plug-in PV cells.

5.5.1 Individual investments (on-site)

The most common way that homeowners become a prosumer is by installing a rooftop PV plant. In addition, one can invest in in-house battery storage, a heat pump or electric vehicle to increase the rate of self-consumption (i.e. the percentage of the PV plant's electricity generated that is used by the prosumer). The last two technologies also contribute to the electrification of heat and transport, a development that can further speed up the energy transition, as discussed in Chapter 2.

Another option would be to install a battery to provide grid-balancing services to grid operators or demand-side flexibility. The battery of an electric vehicle could also be used in this way with smart charging and vehicle-to-grid technology, which allows electric vehicle batteries to store energy according to the conditions in the grid and discharge it back to the grid when it is most needed.

If a homeowner wishes to become a prosumer, the following steps are necessary:

Get an **overview of the costs and benefits** of the different assets that might be used, such as the PV panels, the battery, heat pump or electric vehicle, by, for example, approaching installers.

- Collect **information on support schemes and other regulations** relevant for the prosumer. In many countries, support measures are implemented to foster the energy transition. It is important to carefully assess the support conditions, as, for example, heat pumps with poor efficiency or PV plants with high installed capacity might be excluded, and there may also be a time limit on the scheme. National and local regulations on authorisation and licensing may also need to be taken into account. Information about support schemes and other relevant policies can typically be collected from government websites. In many countries, local energy agencies or consumer organisations can also help.
- After assessing the costs, benefits and support schemes, based on offers from different service and technology providers, the homeowner can **select one (or several) specific products**. Then, they can install the plant and become an active prosumer.

5.5.2 Collective prosumers in one building

Collective prosumers in one building (e.g. an apartment block) typically have the same potential to become prosumers as individual homeowners. Implementing collective prosumption is, however, much more complicated. The ideal way to achieve self-consumption and self-generation in an apartment block largely depends on how national regulation determines which forms of cooperation are possible for using the house or apartment block's rooftop, for example how costs are shared between the individual households. In any case, if a resident of an apartment block plans for prosumption in the building, they need to coordinate with the other residents.

The differences between countries can be seen by comparing the situation in Greece and Germany. While in the Greek case (see Section 7.2) prosumers in one apartment block can jointly make use of a PV rooftop plant, regulation in Germany is very complicated and, in many cases, a joint investment is not possible.

5.5.3 Community investments

Energy communities are the most diverse group of prosumers. In principle, this form includes all different forms ranging from very integrated quarters (such as Hvide Sande or Schoonschip) to national energy communities (such as Som Energía). For such energy communities, a larger number of investment options is suitable, because they are not restricted by the size of the roof or a cellar. They may also have more financial resources if they choose to allow and attract more participants. Thus, energy communities can invest, for example, in a wind turbine, a solar field, a large battery or district heating.

Different legal forms and business models exist for energy communities. These forms differ in terms of the liability of individuals involved in the entity, as well as the members' right to co-determination. The latter can be organised by giving participants the right to vote or through representatives elected by the participants. The most common legal form is the cooperative, which combines a limited liability with an equal voting right for every member independent of their shares. Cooperatives can also build groups of cooperatives (as in the case of Bürgerwerke in Germany) or cooperate with companies to realise a common project.

If an individual is interested in entering an energy community or cooperative, the following steps can be followed:

- Search for a community or cooperative project in the region and assess its conditions for membership or participation. The spectrum can range from very active participation in a cooperative to a passive membership of a cooperative or even only a rental agreement with a company offering collective grid services.
- Decide if any of the existing energy communities are suitable for one's preferences and situation.

If no energy community yet exists or the existing ones do not fulfil the individual's requirements, a new energy community can be founded. This will, however, involve a longer process and more expertise and effort than joining an existing organisation. The process typically starts with the gathering of a group of like-minded people (e.g. neighbours, other fellow villagers or townspeople or existing groups such as sports clubs). One of the first decisions that then needs to be taken is to define the legal form of the energy community. Again, the actual implementation largely depends on national and regional regulation, and national associations or government institutions may help with the necessary expertise.

5.5.4 Participation in company-led projects

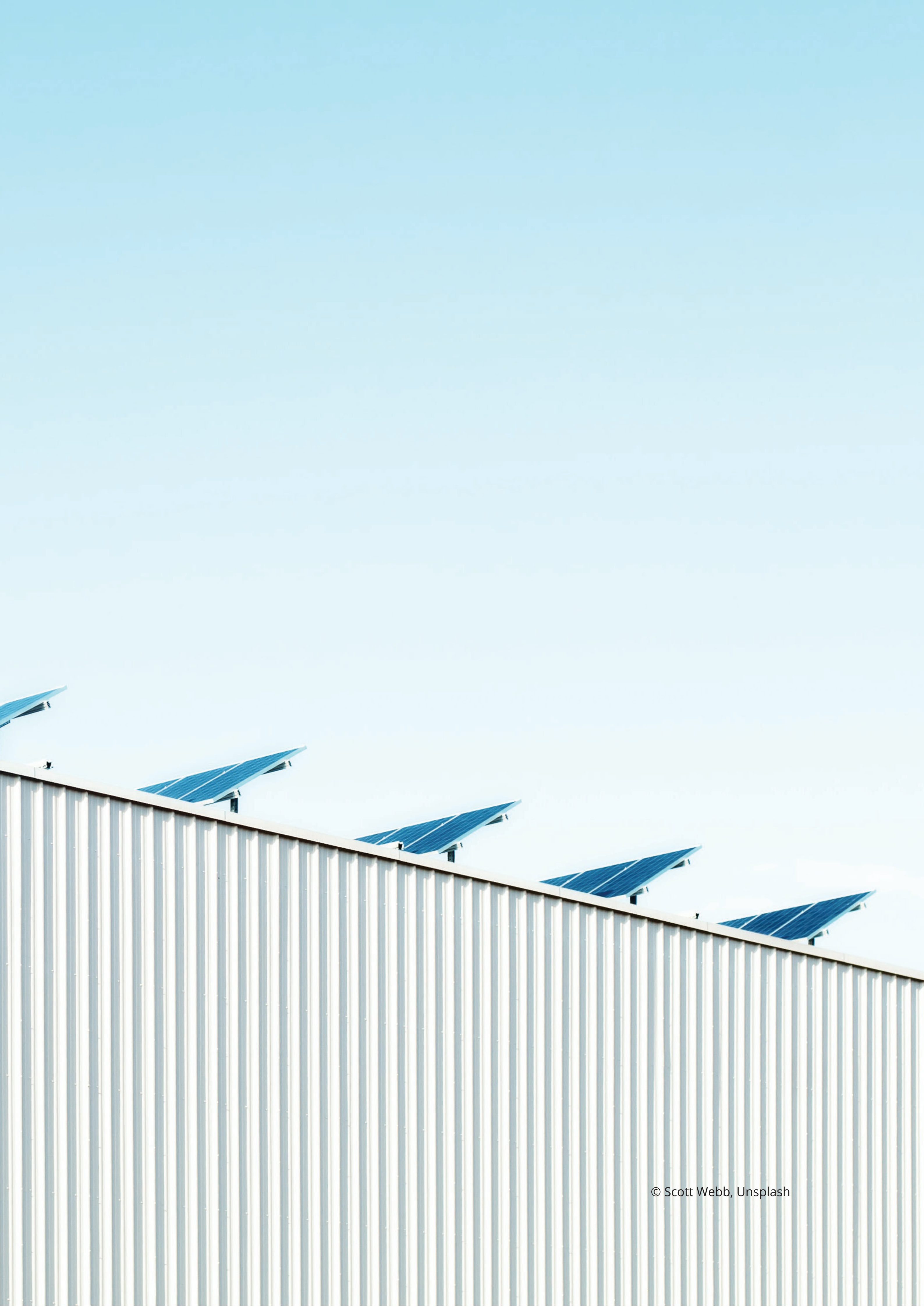
A different way to actively participate in local or regional renewable energy projects is initiatives in which individuals participate in a company-led project. This typically entails mainly a financial participation and requires little or no additional effort or technical expertise. The case of Compile (see Section 4.4) is an example of such a company-led project. In this type of project, the company leading the development will be responsible for the legal and financial aspects, as well as the practical implementation. It will also be able to provide the necessary information about the cost and benefits of participation to interested individuals. Most tenant electricity projects in Germany fall into this category. In this model, a commercial service provider or the building owner finances and operates a PV plant on an apartment block. Tenants in the building can then choose the plant operator as their new electricity provider — with favourable conditions.

5.6 Public institutions and utilities

Public institutions and utility companies also have the potential to engage in prosumption. Public institutions, such as municipalities, usually have several public buildings in a village or town where technologies for collective prosumption can be deployed. For example, a PV plant on the school's rooftop can be used to heat the public swimming pool.

Furthermore, public institutions or utilities can also engage with citizens who are interested in participating in prosumer concepts. For example, institutions can organise joint energy projects with options for households and SMEs to participate, for example with local or regional associations supporting businesses or advising on energy efficiency. Another option is for municipalities to become members of energy communities, which can increase trust in the organisation and facilitate administrative procedures.

Such efforts by public utilities are often helpful, as the initial founding of an energy community often requires upfront efforts in information and acquisition campaigns, public consultations, economic and legal feasibility studies and technical planning. As individuals often lack such resources, the engagement of public utilities or professional facilitators can support prosumer initiatives.



6
Benefits, challenges and drawbacks of prosumption

Prosumer projects can have a wide range of social, financial and environmental benefits for prosumers themselves and for society as a whole. The main environmental benefits are similar to those of utility-owned renewable energy source (RES) projects: reductions in greenhouse gas (GHG) emissions and air pollution. The social benefits may be greater for prosumers than for utility-scale projects, though. Prosumption can increase public support for renewables, citizen empowerment and sense of community. However, a number of drawbacks and challenges also emerge, which need to be taken into account when designing policies and regulations.

In view of the variety of types of prosumption presented in the previous chapters and illustrated by the case studies in Chapter 4, this chapter can provide only general insights into the key benefits, challenges and drawbacks. A more detailed assessment of the impacts of a prosumer initiative or project would need to take the specific circumstances and national policies into account, which vary greatly throughout Europe.

When assessing the impacts of prosumption, as we do here, a key question has to be: What are the benefits and challenges being compared with? Do we compare prosumption with the fossil fuel-derived energy that is being replaced or with utility-based renewable energy production and distribution? The impacts may be quite different. While identifying and comparing the benefits of prosumption with fossil fuel technologies are relatively easy, a comparison with a more centrally organised RES-based system is more challenging, as the result depends on a number of factors that are often country specific. Since both comparisons may be relevant considerations for the reader, we discuss both in this chapter.

6.1 Benefits

Prosumption can benefit the participating individuals, as well as society as a whole. At the individual level, it can offer a means of empowering citizens by allowing them to actively invest in RES, reduce their fossil fuel use and increase their independence from the large energy utility companies. Depending on their specific situation and the policies in their country and region, they can also get an attractive financial return on their investment, reducing their energy costs over time (Brown et al., 2020). On a societal level, prosumption models contribute to the transition to a climate-neutral energy system, improve energy security, reduce CO_2 emissions and increase the 'sense of community' at a local level. Other benefits, such as the creation of local jobs, avoided land use, avoided transmission costs and increased grid flexibility have also been reported (Farrell, 2016).

The main benefits of prosumption detailed in this section belong to the following categories:

- environmental benefits
- social benefits
- financial benefits.

6.1.1 Environmental benefits

Prosumers that generate their own energy or contribute to RES production in an energy cooperative create various environmental benefits. First, their efforts lead to an increase in the use of RES, which reduces the need for energy produced from fossil fuels. This contributes to the reduction of GHG emissions and the transition to a climate-neutral energy system (EC, 2018). With the exception of biomass burning, RES projects also reduce the air pollution typically associated with fossil fuel use. Energy storage and demand flexibility options are a key enabler for integrating higher shares of fluctuating wind and solar energy into the system and replacing fossil fuel power plants at peak demand times to ensure grid balancing. Note that these benefits are all compared with fossil energy sources and that they can also be achieved by renewable energy generation, energy storage and demand flexibility provided by utilities and other non-prosumers (Petrick et al., 2019a).

Another type of potential environmental benefit of prosumption is a reduction in the amount of land required for producing RESs, as long as the existing infrastructure and already occupied land are used. Through prosumer projects, the available rooftop area can be used for solar energy generation, which reduces the need for wind and solar energy generation elsewhere. This effect can be expected to reduce the overall impact of RES generation on, for example, biodiversity (Petrick et al., 2019a). Similarly, a decision to install a heat pump or solar-based district heating system can reduce the need to use solid biomass for decarbonising heating, thus reducing pressure on forests.

6.1.2 Social benefits

Social drivers are a key factor for prosumer developments, although they have not yet been explored in detail. Households and individuals become prosumers in part because of social issues, such as their climate change concerns or because of the positive effects of an energy cooperative on their social community (Horstink et al., 2019).

From the perspective of society, the participation of citizens in the energy system also has benefits compared with a centralised system dominated by commercial energy companies. The main social benefits of prosumption are:

Public support for RESs. Not all citizens applaud large-scale RES deployment. Many people are generally in favour of RES but some oppose projects in their neighbourhood. Large-scale wind and photovoltaic (PV) plants raise concerns about the visual impact on the landscape and — in the case of wind energy — about noise, moving shadows and blinking lights. However, when an individual owns a share in a wind energy project, they are more likely to accept the wind turbine near their home and wind turbines in general. They then directly participate in and benefit from the energy transition, which can outweigh the potential drawbacks. Therefore, prosumption may increase public support for RESs, helping to ease the transition towards a climate-neutral energy system (Petrick et al., 2019b).

Empowerment. Prosumption increases the empowerment of citizens, since they have a chance to become stakeholders in the energy system (Petrick et al., 2019a). In a centralised system, citizens rely on commercial energy companies and have no say in decisions about their energy supply.

Local job creation. This is mentioned as a potential benefit in the literature, based on the assumption that prosumers will be inclined to hire local contractors for their projects. However, this effect has not yet been quantified.

Sense of community. Collective prosumer initiatives have the potential to increase the sense of community. Members of collective prosumer initiatives are often unpaid volunteers from the same neighbourhood. When these members collaboratively invest in RESs, and often also collectively develop and then operate a project over many years, they may feel a closer connection to their neighbours (Horstink et al., 2019).

Fairness of distribution of benefits. The transition towards a climate-neutral energy system offers economic opportunities for investors, through profits and reduced energy costs or remuneration for energy services supplied. Both individual and collective prosumption models allow those financial benefits to be shared more widely among citizens than with large-scale commercial projects. In particular, projects with small or no entry investments — such as Som Energía — enable all citizens to profit, including those who do not own property in which direct RES investments can be made. This can strengthen public support for energy sector transformation.

These social effects of prosumption have been reported but they are typically anecdotal. Research into its effects on public support for renewable energy, citizen empowerment and impacts on the sense of community is still limited, and these effects have not yet been systematically measured and quantified. Moreover, it is not trivial to disentangle causes and effects. For example, in a survey of 1,075 households in Berlin that have the option of participating in a tenant electricity scheme, 60% of respondents who participate in the scheme stated that the project had stimulated their interest in the energy transition compared with only 22% of those who chose not to participate. However, the survey also showed that those who choose to participate were more concerned about climate change than the average German citizen — a main reason why they joined the scheme in the first place (Umpfenbach and Faber, 2021).

6.1.3 Financial benefits

Under the right circumstances, prosumption models can have financial benefits for individual citizens. Prosumption may lead to lower energy costs, and selling excess energy may lead to revenues, especially in the current context of historically high energy prices. Furthermore, by generating their own energy, prosumers might be better protected from price fluctuations. In countries where fossil heating fuels are subject to carbon pricing, RES heating technologies, such as heat pumps, can also reduce a household's costs compared with the fossil fuel alternative. In fact, a study for the European Commission in 2018 found that financial considerations were the main driver for consumers who invested in PV systems in residential areas (GfK Belgium Consortium, 2017), although environmental concerns also scored highly. A survey of Berlin tenants who had the opportunity to join a tenant electricity scheme showed the same results (Umpfenbach and Faber, 2021). Whether prosumption is financially feasible in a given situation depends on the cost of prosumer technologies compared with the alternatives, with price differences being shaped by the regulatory framework (see also Section 7.1).

Prosumption can also have financial benefits for society as a whole. For example, self-consumption of households with PV plants, possibly in combination with batteries and flexible demand options, may not only reduce the need for transmitting power over long distances and decrease grid-balancing costs but may also reduce both grid investments and land use requirements (Dehler et al., 2015; Petrick et al., 2019a). However, whether this is indeed the case, depends on the local circumstances. Furthermore, expanding the transmission grid has multiple benefits, irrespective of prosumption, for example to enable better use of the balancing effects of different wind regimes across Europe than at present or more generally to increase system flexibility. Likewise, grid extensions at local level will need to take place during the energy transition, to adapt the grid to the increasing number of electric vehicles and heat pumps and to decentralised renewable energy generation by utilities and energy companies.

Furthermore, prosumption entails investments in renewable energy, which are financed by prosumers — debt and equity based. In the case of equity-based financing, prosumption could leverage capital at relatively low costs, as citizens are in general less risk oriented and have often lower opportunity costs of capital than large private investors. This can speed up RES growth, as it attracts funds that would not otherwise be available. Financing at the local level could also engage local banks, which in turn strengthens the local economy.

Finally, prosumers can also contribute to energy security. The diversity of participants and models, and the decentralised nature of prosumption, can strengthen the energy supply. Being often small-scale projects, prosumers are also able to deploy RESs relatively quickly in response to periods of high energy prices and volatility, protecting users and enhancing the general resilience of the system.

6.2 Differences between prosumer models

Some of the benefits we have discussed apply to all prosumer models, but some may apply only to certain prosumer models. Table 6.1 provides an overview of the benefits we discussed above and shows whether these apply to individual prosumers, collective prosumers and small and medium-sized enterprises (SMEs) and public organisations (Petrick et al., 2019a). Green shading indicates a benefit of the type of prosumer model. Orange shading indicates that there may be a benefit in some cases. No colour shading indicates very limited benefits.

Table 6.1 shows that the social benefits mainly apply to collective prosumer initiatives. Individual prosumer initiatives contribute only to empowerment and public acceptance.

All prosumer models contribute to reducing GHG emissions and thus have environmental benefits. Individual prosumer models have less impact on biodiversity and the ecosystem than the collective prosumer or SME and public organisation models, but this will depend on the scale and location of the projects and whether or not they require land.

The viability of business cases differs between individual and collective prosumer models. However, it also depends on the type of technology that is used and, most importantly, the policy framework. Furthermore, collective prosumer models exist in a wide variety of forms. Therefore, whether prosumer models are feasible or not depends on the situation.

Table 6.1 Overview of the benefits of the various types of prosumer

Benefits	Individual prosumers	Collective prosumers	SMEs and public organisations
Environmental			
GHG emission reduction	All types of renewable energy prosumers contribute to reducing GHG emissions when compared with fossil-fuel based systems.		
Reduction in land required for renewable energy production	Rooftop PVs can reduce the amount of land used for RESs; heat pumps may reduce biomass use; and local production and use can reduce the need for transmission lines.	Same benefits can be achieved as for individual prosumers, but land-based PV installations or wind turbines are also possible.	
Social			
Public support for RES	All types of prosumer models contribute to public support for RES.		
Empowerment	All types of prosumer models increase empowerment, since citizens/parties are (partly) responsible for their own energy supply. Not all citizens may have the opportunity to invest and get actively involved, but our case studies of Som Energía and Compile do illustrate that investment requirements can be low.		
Sense of community	Limited.	Prosumers from a community work together to produce their energy.	Depends — citizens from a community may work together.
Fairness of distribution of benefits	Allows participation of those citizens who own buildings.	All participants in a community or collective could benefit from RES technology.	At least allows participation of SMEs and public organisations acting for the benefit of the community.
Financial			
Benefits and revenues for prosumer	Depends on various factors, e.g. type of business model, costs of prosumer technology and policy framework.		
Less grid investment	The effect on grid investment is highly dependent on the local grid conditions.	If the collective is local, decrease in energy transport depending on local grid conditions.	The effect on grid investment is highly dependent on the local grid conditions.
Access to finance for RESs	All prosumer models create access to funds for investment in renewable energy projects.		

6.3 Barriers

Citizens may face barriers that may prevent them from becoming prosumers, even in cases where they have the technical opportunities and the financial resources.

The main types of challenges and barriers that prosumers experience are described in the following subsections. The practical implications of these barriers are addressed further in the following chapter. Many of these issues can be resolved, mainly by effective government policies (see Chapter 7). The degree to which policymakers want to foster prosumption should also depend on the system-level impacts and drawbacks.

6.3.1 Regulatory barriers

In some countries, prosumption is not properly incorporated in the national laws and regulations. Prosumers may then face legal barriers, for example some prosumer models may not be allowed (Toporek and Campos, 2019). This mainly applies to collective prosumer models. Furthermore, current energy market regulations may be a barrier for prosumers to offer energy storage or demand response services. In the Netherlands, for example, energy prices for small-scale consumers are not allowed to vary during the day in line with the actual market price. This prevents prosumers from receiving a price signal that would encourage energy storage and demand responses in times of low electricity prices when wind and solar production are high.

Policy uncertainties can also create a barrier: if people are unsure whether a certain policy will remain in place, or if the policy for the coming years is not yet decided upon, they will be hesitant about investing. This policy uncertainty creates an uncertainty regarding the profitability of a project (see, for example, Laes et al. (2019)). Furthermore, regulatory and administrative complexities can also deter potential prosumers (this relates to lack of knowledge and expertise, discussed below).

More broadly, certain energy policies can affect the competitiveness of renewable energy prosumers, such as fossil fuel subsidies.

6.3.2 Financial barriers

Most potential prosumers will consider participating in a project only if it leads to an attractive return on their investment, or if the project does not significantly increase the cost of their energy supply (Horstink et al., 2019). Not all prosumer models have a viable business case.

Furthermore, becoming a prosumer often requires a significant upfront investment in renewable energy technology. The financial benefits, typically lower energy bills over the lifetime of the technology, may not be enough to compensate for these investments. In addition, many households will not have access to the funds necessary to invest at all. Various publicly financed incentive schemes can improve the business case for prosumers, for example with net metering or feed-in tariffs (see Section 7.2 for more information on these policies). However, if such public support is established, distributional effects might occur, depending on the mechanisms financing these measures, as discussed in Section 6.4.

6.3.3 Technical barriers

In some cases, it may be impossible for citizens to become prosumers because of technical limitations and barriers. For example, energy infrastructure must be present to transport the energy produced, or their current electricity meter may not allow them to feed the energy they produce into the grid (Horstink et al., 2019). There may also be geographical or other practical barriers to deploying a specific technology. For example, a rooftop must be available with sufficient access to the sun for solar PV or thermal panels to operate effectively.

Technological barriers also reduce the benefits that prosumers may have on a system level. To make optimal use of the potential for energy storage and demand response that prosumers can provide requires new technological solutions, such as energy sensors, smart grids and further digitalisation of the energy system (Good et al., 2017; PVP4Grid, 2020b). Furthermore, whether or not such decentralised flexibilities can compete with other more centralised solutions needs to be assessed.

6.3.4 Social barriers

Setting up and operating an energy cooperative requires dedicated effort and an effective organisation. Many are run by volunteers: a survey in eight EU countries found that 72% of all staff were unpaid in the 198 prosumer initiatives that responded, but volunteers accounted for a much smaller proportion of staff in projects in which the public sector or companies were in charge (Horstink et al., 2019). This creates social benefits, but it also creates a barrier and risk. Interested citizens will need to gather sufficient volunteers to initiate and sustain the project before they can develop and realise their ideas.

6.3.5 Lack of knowledge and expertise

To set up an energy cooperative, the initiators and founders need to be aware of the relevant policies and legislation and have at least a basic knowledge of the relevant RES technologies and of the financial aspects of such a project. Setting up an energy community also requires legal expertise to draw up proper contracts between the parties involved, to address ownership, organisation, financial aspects, liabilities, etc. For example, in the Schoonschip case, the interdependencies between the participants are formalised in participants' agreements and a 'Schoonschip agreement', which stipulates the arrangements for reservation of the lot, compensation for costs incurred (registration fee, planning cost and collective utilities), financial statements, leasehold agreement and various other requirements (Schoonschip, 2021b). Lack of knowledge about the various topics relevant for prosumption can therefore also be a barrier to the developments.

More broadly, there is a general lack of skilled workers in the field of renewable energy, which acts as a bottleneck for the development of new projects (EC, 2022). Vocational training should be promoted at national and local level in order to close the skills gap.

6.3.6 Differences between prosumer models

Table 6.2 gives an overview of the most common barriers and challenges and indicates whether these affect the different types of prosumer models. Orange shading indicates that a barrier applies to the type of prosumer model. Green shading indicates that there may be a barrier in some cases. No colour shading indicates that no significant barriers apply.

Table 6.2 Overview of barriers and challenges for the various types of prosumer

Barrier	Individual prosumers	Collective prosumers	SMEs and public organisations
Legislative			
The current, uncertain legislative setting	Regulation for individual prosumers is relatively well developed.	The rules for energy production by collectives, e.g. energy communities, are not clear in some countries (Toporek and Campos, 2019).	Relatively clear rules when acting as individual prosumer entities. Less clear when acting as part of a collective.
Financial			
High cost to end consumers	Depends on the specific case and the country-specific regulations. Not all prosumer models have a viable business case.		
Access to finance	Investments in RES technologies are significant. Depending on the country and individual context, it may be difficult for individual prosumers to get the necessary financing.	Sometimes. It is easier for collective prosumers to get the necessary financing, since the investment is split between all participants in the collective.	Sometimes. It is easier for SMEs and public organisations to get access to finance than households, but the investments required are also larger.
Technical			
Required energy infrastructure not present	Self-consumption with PV panels usually requires no additional energy infrastructure.	Yes. Usually, power grid reinforcement is necessary for new collective prosumer projects, e.g. wind turbines or solar fields. This is perceived as one of the main negative factors by collectives (Horstink et al., 2019).	Self-consumption with PV usually requires no additional energy infrastructure.
Lack of knowledge			
Lack of knowledge of legislation, policies and renewable energy technologies	Often, households have little specialist knowledge.	Since collectives have multiple members, they have more knowledge. However, legislation for collectives is usually more complex. This is perceived as one of the main negative factors by collectives (Horstink et al., 2019).	Depends. Some SMEs and public institutions have knowledge of legislation and policies, but certainly not all of them. One challenge here is that energy is not the core business of most SMEs and therefore is often neglected.

6.3.7 How can these challenges be tackled?

To further enable citizens who may be interested in becoming prosumers, the challenges and barriers we described in the previous section have to be addressed. Different stakeholders have to tackle these challenges. Table 6.3 gives an overview of how the challenges and barriers can be tackled and which parties are responsible (Petrick et al., 2019a). Some of these actions have become mandatory with recent EU policies, such as the need to implement proper definitions of legal forms of prosumption and prosumers' rights (see Section 7.1). Other actions require more detailed assessments at the national or local level to determine the extent to which they should be implemented. Policymakers should carefully weigh up the impacts on prosumers, non-prosumers and the energy system as a whole (see Section 6.4). The specific situation and the political preferences will then determine the level of support that will be given to prosumers and the need for infrastructure reinforcements.

Table 6.3 How to resolve the barriers and challenges

Barrier	Prosumer model	How can it be tackled?	Responsible stakeholders
The current, uncertain legislative setting	Mainly collective prosumers	Proper definition of legal forms of prosumer models and prosumers' rights in legislation.	EU National governments
High cost to end consumers	All prosumer types	Support schemes or grants	EU National governments Local governments
Access to finance	Mainly individual prosumers	Support schemes or loans	National governments Local governments Banks or other financial institutions
Required energy infrastructure not present	Mainly collective prosumers	Timely grid reinforcements	Grid operators National governments
Lack of knowledge of legislation and polices	All types of prosumers	Information campaigns, market roles for professional facilitators and service providers.	National governments Local governments
Lack of knowledge of renewable energy technologies	All types of prosumers	Information campaigns, market roles for professional facilitators and service providers.	National governments Local governments Associations and non-governmental organisations, e.g. REScoop

Box 6.1 Impacts of prosumption on energy povert

Prosumption has the potential to benefit vulnerable consumers and contribute to reducing energy poverty, but only under the right policy conditions. High energy prices and low incomes are the main cause of energy poverty. When energy-poor households become prosumers, their energy bills will stabilise and they are better protected against increasing electricity prices. Moreover, in many cases, self-produced electricity is already cheaper than electricity bought from the grid (Petrick et al., 2019a), although this will depend on support policies.

However, socially inclusive measures are necessary to help low-income households become prosumers or protect them from negative impacts caused by the growth of prosumption. They lack the money to invest in renewable energy technologies, and in many cases they do not own a rooftop, but they may be faced with higher energy costs and grid charges. With current policies and tariff structures, the energy costs for non-prosumer households are typically expected to increase when the share of prosumers increases (Petrick et al., 2019a). Therefore, specific support measures that prioritise energy-poor households may be necessary to prevent an increase in energy poverty as a result of these developments.

6.4 Drawbacks of prosumption versus utility-owned renewable energy production

Despite the benefits of prosumption, we can also identify a number of drawbacks compared with centralised renewable energy production. Furthermore, there are some aspects where the effects of prosumption can either be positive or negative, depending on the local situation.

First, there are a number of issues related to the potential drawbacks of prosumption on the energy system as a whole:

Financial. Per energy unit, large-scale systems are cheaper and more cost-efficient because of the economies of scale. Therefore, an energy system with a large share of prosumers will cost more per unit. Total energy system costs depend on the need for investment in grids and balancing services that each system generates. Yet, it is extremely difficult to fully disentangle the causes and effects, as a number of country-and region-specific factors play a role here, including the overall energy mix, availability of storage and interconnections with surrounding areas, building stock and availability of district heating grids, as well as the adoption rates of electric vehicles, smart meters and hydrogen production sites. Thus, the assessment of total costs is not static but can change over time as we progress towards a fully decarbonised energy system with more advanced integration across sectors.

Efficiency of the energy system. Usually, large-scale systems are more efficient than small-scale prosumer systems. Developers of large-scale systems can choose the ideal location and technology to optimise energy production. Prosumers with smaller local installations have fewer options, which may lead to less optimal systems from an energy-efficiency point of view, for example PV panels on homes in northern European countries. A less-efficient energy system leads to higher costs, more use of space for energy production and the use of more raw material. On the other hand, as mentioned in Section 6.1, prosumers can also have positive impacts on the overall energy system. When they combine energy generation with energy storage or demand flexibility to increase their self-consumption, they may reduce both the pressure on the electricity grid and the need for balancing services, compared with a more centralised energy system.

Rebound effects. Since prosumers produce their own energy, they may be tempted to use more energy, either by buying more energy-consuming equipment or by raising the temperature in the house with a heat pump. This will lead to an increase in energy use, which partly cancels out the benefits of prosumption.

A number of issues are related to the current regulations and policies, which are not yet optimised for an energy system with a large number of prosumers:

Cost for non-prosumers. This dynamic may also lead to the effect that households that cannot become prosumers will bear an increasing share of the financing of the electricity grid. This may increase energy poverty, as low-income households typically have fewer opportunities to become prosumers — see next page. The same may be true for other financing mechanisms that are based on electricity consumption, such as renewable energy support (EC, 2016a). This can be resolved by regulatory changes that ensure that prosumers also contribute to these costs (Winkler et al., 2014).

Eroding the base for grid and energy system financing. Today, some of the most common prosumption models are economically viable for investors because they enjoy exemptions from grid charges, taxes and levies. If system costs remain stable, this implies higher charges for non-prosumers and thus raises concerns about fairness. Exemptions can be justified if prosumers reduce grid costs or provide balancing services, as in the case of Schoonschip; nevertheless, in many support schemes, exemptions are not tied to any conditions and doing so will be a challenging task because of the trade-off with keeping the regulatory framework simple and accessible. However, if prosumption is to exploit its full potential, regulators will have to devise new ways to finance the grid and all the services it provides — also to prosumers — in an equitable fashion that sets the right incentives for system-friendly investments and behaviour.

Underused rooftop PV potential. A regulatory framework that favours self-consumption as the only economically viable model for rooftop PV installations forces investors to maximise self-consumption rates. Therefore, many prosumers install PV plants that are smaller than the available rooftop area. This has been the case in Germany since 2012, when PV feed-in-tariffs for rooftop plants dropped below retail power prices. In most cases, prosumers can achieve break-even for their PV investment only if they optimise the share of self-consumption. Consequently, average roof plant sizes and overall installation rates have decreased (Kelm et al., 2019). This does not only apply to individual prosumers but also to collective initiatives such as tenant electricity schemes (Umpfenbach and Faber, 2021). Making self-consumption and grid export equally profitable could be one solution to address this issue and encourage use of the available rooftop area. This can reduce the need for space for renewable energy production elsewhere ([13]).

([13]) Whether or not this benefit outweighs any additional cost due to the smaller scale of rooftop PV than larger scale RES production will depend on the specific situation and the scarcity of space for RES projects in a given region or country.

Low-income groups lacking the opportunity to become prosumers. In principle, prosumption can help to spread profits from energy investments more evenly across society, but only if all citizens do indeed have the opportunity to become prosumers. In practice, many do not own a rooftop or do not have the capital or time to spare for investing in an energy community. It is therefore key that collective prosumption schemes, in particular, have low entry barriers, i.e. low thresholds for investments and low administrative demands. The Som Energía case study, where the membership fee is limited to EUR 100, is a good example, and tenant electricity schemes that require no investment are another (Umpfenbach and Faber, 2021). The Schoonschip community, however, is based upon collective ownership and requires an upfront investment of EUR 70,000. In the future, shifting energy use based on dynamic tariffs may also be a prosumer activity that does not require upfront investment.

Both decentralised energy production by prosumers and centralised energy production by energy companies have their benefits and disadvantages, and both are reasonable for a robust climate-neutral energy system (EC, 2018). An ideal energy system will thus consist of both prosumers and large-scale systems. The optimal share of both is then likely to vary throughout the EU, depending on local circumstances.

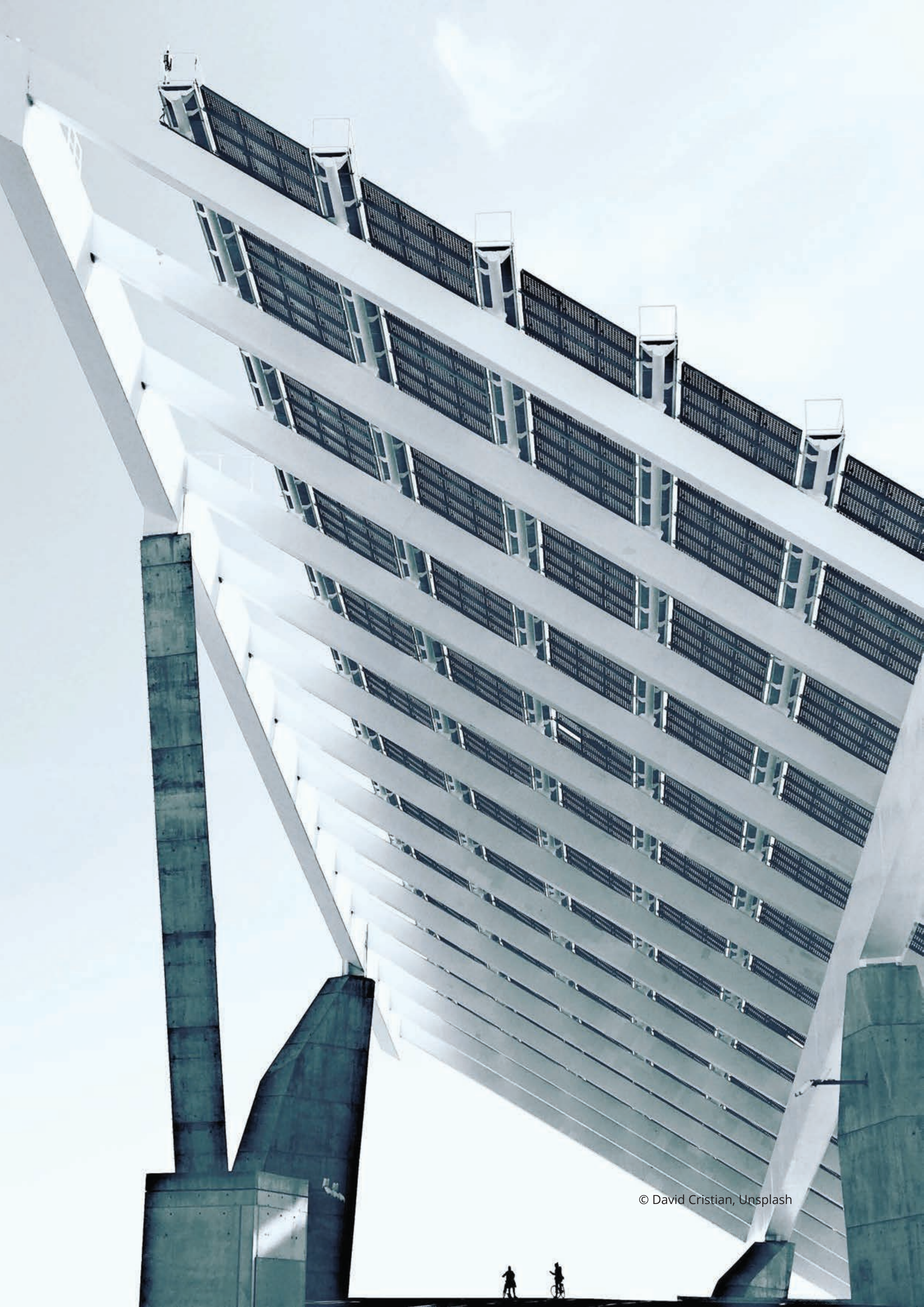
Box 6.2 Impacts of prosumers on the grid

It is often said that prosumer projects can have a positive impact on the power grid since they bring electricity production and consumption closer together. However, this is not always the case; in many cases, prosumer projects may increase rather than decrease the need for grid expansion.

Grid capacity has to be sufficient for the times of peak demand and supply, and both electricity demand and supply may increase because of prosumers. Self-consumption may reduce the need to transport energy to and from a location, but grid expansion may still be necessary if the level of self-consumption varies throughout the year. In that case, peak loads on the grid — due to temporary high demand for or supply of electricity — cannot be avoided at all times. The advent of electric vehicles, heat pumps and air conditioning, in combination with a high photovoltaic installation rate will then increase the need for increased grid capacity despite flexibilities in the system. In addition, uncoordinated charging and discharging of batteries can cause unpredictable production peaks. Additional grid investments may also be unavoidable in grid areas with a low demand and big rooftop areas. This might typically apply to collective prosumer models, in which the energy production locations can be some distance from the demand and storage sites.

The technical and market opportunities for prosumers to reduce their impact on grid investments may also be limited by policies and regulations, which are not yet aimed at encouraging self-consumption in many countries ([a]). There seems to be considerable potential to improve grid integration of self-consumption and decentralised energy storage. This requires new technology, as well as new regulations and policies, and research into this topic is ongoing. The Schoonschip community, for example, uses an exemption to the Dutch electricity law to own and operate its own grid, so that it can use and store the energy it produces as much as possible within the community. The Council of European Electricity Regulators qualitatively addresses issues that may arise regarding consumer rights, balancing and flexibility of the energy system, and grid ownership, operation and development (CEER, 2019). A recent paper by the Regulatory Assistance Project explores how Member State governments and regulators can ensure that energy communities deliver benefits for the operation of electricity grids, discussing topics such as aggregation and network tariffs (RAP, 2021).

([a]) For more information on the policy framework necessary to enhance these benefits on grid investments, see Petrick et al. (2019b).



7
How can policy affect prosumption?

The recast Renewable Energy Directive and Internal Market in Electricity Directive defined various prosumer types and set out detailed rights and obligations for each. The 'Fit for 55' policy package and, especially, the recent REPowerEU plan further highlight the role of prosumers as key actors in achieving Europe's climate and energy security objectives. Key levers to address at national level are simple and stable support schemes, fair tariffs for exported energy, clear rules on self-consumption and simple administrative procedures.

As the energy system shifts towards an increasing share of renewable energy, EU and national government policies and regulations also need to adapt. Policies are a driving force for increasing renewable energy generation and enabling citizens to contribute to these developments. Market regulations need to be adapted to enable prosumers to develop attractive business models, while making sure that prosumer models are responsive to system-level needs (CEER, 2019; Brown et al., 2020).

This is a tremendous challenge for policymakers, since the new energy system is still in the process of emerging. While it is now clear that the new system will be fully decarbonised and heavily integrated across sectors, it is less obvious how the system will be regulated in the future. How will renewable energy investments be financed? Will power price-setting mechanisms change? How will the grid be financed, and how can those costs be shared fairly among grid users? What measures are necessary to ensure grid stability in an entirely decentralised system? Which mechanism can incentivise flexibility in demand and supply?

The regulatory framework for prosumers is closely linked to these fundamental questions. It needs to strike a balance between system needs and enabling citizen engagement in the energy system, which is a central prerequisite for accelerating change. The EU policy framework sets out the rights of prosumers, increasingly making them key actors in the energy system transition. The implementation — and interpretation — of these rules, however, varies among Member States. Best practices can be identified in some countries, at both national and sub-national levels, but more changes are required to reshape the regulation of the energy system in such a way that prosumers can become pillars of the system rather than a niche phenomenon.

While this chapter focuses on the EU and national levels, municipalities are also key stakeholders in increasing prosumption. This is explored in an upcoming EEA briefing, which focuses on the role of cities in promoting prosumption and makes recommendations towards this end.

7.1 Prosumption in EU policy

In the 'Clean Energy for all Europeans' package of 2016, EU lawmakers substantially strengthened the rights of energy consumers, including the right to become a prosumer (EC, 2016b). For the first time, the revised Internal Market in Electricity Directive (EU, 2019) defined 'citizen energy communities', while the recast Renewable Energy Directive (EU, 2018b) pledged no discrimination with regard to access to support schemes for 'renewable self-consumers' and 'renewable energy communities'.

The role of prosumers was also highlighted in the 'Fit for 55' package, proposed by the European Commission in July 2021 to implement the EU's goal to increase the reduction in greenhouse gas (GHG) emissions by 2030, and in which energy communities feature prominently (EC, 2021a). For example, the proposed amendment to the Energy Efficiency Directive states that 'Member States should consider and promote the role of renewable energy communities and citizen energy communities' (EC, 2021b). Similarly, references to energy communities and self-consumers can be found in the proposed amendment to the Renewable Energy Directive (EC, 2021c).

The most ambitious and detailed proposal to date for bolstering prosumption at the EU level came in May 2022. In response to the invasion of Ukraine, the European Commission proposed the REPowerEU plan (EC, 2022c), aimed at ending the EU's dependence on Russian fossil fuels while tackling the climate crisis. Among other measures, REPowerEU builds on the European Green Deal, making the roll-out of renewables a central part of this effort and proposing to raise the EU 2030 target for renewables to 45% of all energy consumed. There are three main aspects of REPowerEU that have a direct impact on prosumers:

1. **A Solar Rooftop Initiative**. The core of this initiative is a proposed phased-in legal obligation to install solar panels on new buildings. New large (>250m^2) commercial and public buildings should comply with this obligation by 2026, with existing ones following by 2027. New residential buildings would have to comply with the obligation in 2029. The initiative also limits the time taken to obtain a permit for solar rooftop installations to 3 months.

2. **Levelling the playing field**. REPowerEU acknowledges that 'the full potential of solar energy for the EU can only be exploited if citizens and communities are provided with the right incentives to become prosumers.' Member States would be obliged to establish appropriate incentives and adapt administrative requirements to facilitate prosumption, including providing one-stop shops offering integrated information and support. They should also enable the development of local energy markets and avoid discrimination of self-consumption and peer-to-peer exchanges, including those in apartment buildings. The EU would also work with Member States to set up at least one renewables-based energy community in every large municipality by 2025.

3. **Integration with heating and storage**. As an enabler of increased penetration of renewables, Member States would establish robust support frameworks that integrate solar rooftop installations with energy storage and heat pumps. Furthermore, REPowerEU proposes to double the deployment rate of heat pumps, reaching a cumulative 10 million units over the next 5 years. It also addresses the lack of skills and trained workforce that enables such integration and the wider development of renewable projects.

It is still not certain that all the measures in REPowerEU will reach the final legislative process, or how they would translate into concrete actions. Depending on how they are transposed and applied by Member States, these measures have the potential to greatly increase the number of prosumers and strengthen their role, not only in decarbonising the energy sector but also in enhancing EU's energy sovereignty.

7.2 How can national governments stimulate prosumption?

With the adoption of the 'Clean energy for all Europeans' package, the EU obliged Member States to enshrine the rights of renewable energy self-consumers in national law and to actively support prosumers and energy communities. With this ruling, the EU responded to highly divergent regulatory frameworks at Member State level, many of which do not yet account for prosumers and energy communities in their energy market framework (Toporek and Campos, 2019). The process of transposing the EU rules into national laws is not trivial. Implementation is not merely a matter of translating EU rules: it requires further definitions and operationalisation with respect to the type of entities or business models that qualify as prosumers and energy communities and with respect to what constitutes fair treatment and active support. To date, transposition is still incomplete, and some Member States have undertaken it in a superficial manner, lacking definitions and clarification of key concepts (CAN Europe, 2022). REPowerEU tries to overcome some of these shortcomings, encouraging Member States to fully implement existing EU legislation and proposing new measures. It is therefore important that countries learn from others' experiences that can guide their progress. The following section describes some of the key elements that have emerged as central framework conditions for prosumption, illustrated with exemplary measures taken from various Member States.

The national regulatory framework governs the relationship between prosumers and the grid and regulates the increasingly diverse prosumer business models (Brown et al., 2020). In defining support scheme rules, national governments determine how difficult or easy it is for individual and collective prosumers to invest in renewable energy installations. Feed-in-tariffs remain a key enabling tool for prosumers in many Member States, especially for individual prosumers who invest in small PV systems. In countries or for segments without feed-in tariffs, regulators can guarantee that prosumers receive at least the market value for the electricity that they export to the grid. This is, for example, the case in Spain and the United Kingdom (Hall et al., 2020).

A key factor enabling or hindering prosumption is regulatory complexity. As the Som Energía case study shows, tenders to access support for larger renewable energy installations can require a significant amount of professional and administrative input for participation, increasing the demands on energy communities that aim to invest jointly. To address this issue, the Irish government set up a separate tender scheme that exclusively supports community-led projects. To be eligible, projects must be 100% owned by a renewable energy community and members must live close to the project (Sustainable Energy Authority of Ireland, 2021). The German government also introduced preferential treatment for energy communities in tenders for wind projects in 2017; however, they needed to adapt this rule in the next revision to counter misuse by commercial entities sailing under the flag of an energy community. In its definition of 'citizen energy', the German Renewable Energy Sources Act referred to voting rights, 51% of which need to come from individuals living close to the project. It did not, however, put any restriction on the origin of the investment capital, allowing larger companies to redefine themselves as citizen energy projects (Gsänger and Karl, 2019).

As highlighted in the REPowerEU plan, regulatory complexity linked to licensing, grid connection and administrative procedures in general can also be a hurdle for smaller projects, for example energy-sharing or peer-to-peer trading projects (Toporek and Campos, 2019).

Another central element determining whether an electricity prosumption business model is economically viable or not is the regulations governing network charges, surcharges and taxes on self-consumed and locally traded electricity, as shown in the case study on net metering below. The Compile case study in Slovenia illustrates how restrictions on sharing collectively produced electricity within the local grid can impede local initiatives from growing beyond a certain size. For PV installations, the central prosumer technology in the power sector, the generation costs of small and medium-sized plants tend to be lower than retail power prices, making it profitable to replace grid-based electricity with self-consumption. However, this works only if prosumers are exempt from all or at least a share of the network charges, fees and taxes that make up the lion's share of retail electricity prices in many Member States. This is the case in Germany for self-consumption in installations of up to 30KW_p (kilowatt peak), but it only applies when the plant owner and the electricity consumer are the same person. For PV plants on multi-occupancy blocks, the German Renewable Energy Sources Act has a different support mechanism (Umpfenbach and Faber, 2021). When prosumption models begin to make up a significant share of overall power production, such exemptions can have the effect of increasing the burden from fees and charges for non-prosumers — a key tension policymakers have to address when moving towards an increasingly decentralised energy system (Brown et al., 2020; Umpfenbach and Faber, 2021). For heat generation from renewable energy, the regulatory framework also has a key impact on economic viability, for example the national carbon pricing regimes for fossil fuels used in the heating sectors in France, Germany, Sweden and Switzerland. The carbon price improves the viability of low-carbon alternatives such as heat pumps. The EU proposal to introduce emissions trading in the transport and building sectors EU-wide would extend those effects to the EU as a whole (Agora Energiewende and Ecologic Institute, 2021; EC, 2021).

In addition to creating a level playing field for prosumers and energy communities and for commercial investors in the energy system, the EU now obliges governments to actively support these initiatives through an enabling framework. Financial support can take the form of grants in the project development phase, as in the Schoonschip project in Amsterdam and the Compile project in Luče, or governments can provide grants for large investments, for example in Greece (see Box 7.1) or loan guarantees, as in the Hvide Sande case study. Scotland created a grant and loan scheme called the 'Community and Renewable Energy Scheme' to support community energy projects. Community and faith groups, housing associations, local authorities, national and regional non-profit organisations and rural SMEs are eligible. Furthermore, the Home Energy Scotland loan scheme provides loans to homeowners and private sector landlords for home improvements, which include renewable energy systems, connections to district heating powered by renewable energy and energy storage systems.

Governments can also create temporary regulatory exemptions for innovative approaches. In the Schoonschip case, an exemption enabled the community to operate an island grid, and in Luče, a 'regulatory sandbox' is planned to allow energy sharing (see Chapter 4). Some governments also opt for support schemes that are exclusively available to energy communities. One example is the collective virtual net metering scheme in Greece (see Box 7.1) and the Irish tender scheme for community-led projects described above. Another example is the Dutch 'Postcoderoos' model that supports PV power consumed within one post code area through a tax deduction per kilowatt-hour, but only if the investment is made by a cooperative (Hall et al., 2020).

Finally, prosumer models face a number of regulatory barriers that are independent of energy market regulation. For example, many housing associations in Germany hesitated over installing PV plants on apartment blocks because they feared losing the value added tax exemption for housing services by generating profits from a non-housing-related activity — a barrier that has been removed through a tax code change (Umpfenbach and Faber, 2021).

All Member States are facing similar challenges and, although national regulation needs to be adjusted to national circumstances, a more harmonised framework across the EU may help to disseminate promising models across national borders and enable the development of cross-border projects (EEA, 2020).

Box 7.1 Policy case study: Net metering in Greece

Function of the support scheme

Net metering allows prosumers to offset consumed and self-produced electricity with a temporal deferral. Two meters, or alternatively a dual-flow meter, measure how much electricity a household takes from the grid and subtract the amount of self-generated electricity it feeds into the grid over a certain period, e.g. a year. The energy supplier only bills the difference between the energy consumed and injected to the grid (the 'net' amount). This concept is especially favourable for prosumers with on-site photovoltaic installations, since the daily generation pattern often does not match the consumption profile.

When the levelised cost of a self-generated kilowatt-hour is below the electricity retail price, this concept becomes economically profitable. The profitability stems from the fact that prosumers not only save the procurement costs of the grid-based electricity that they replace with self-generated power, but they are also exempt from grid fees, taxes and surcharges that make up a sizable share of retail power prices across the EU. Some Member States therefore cap how much grid-based power a prosumer can balance out.

The aim is to ensure that prosumers contribute financially to the costs of maintaining the grid and to limit cost increases for non-prosumers (Hall et al., 2020; Σύνδεσμος Εταιριών Φωτοβολταϊκών, 2020; mp energy, 2021; Protergia, 2021).

Three net metering schemes in Greece

In Greece, several net metering schemes exist, which are provided here as examples.

1. Net metering with on-site generation

To be eligible for this kind of net metering, both renewable energy generation and electricity consumption must take place at the same site. Any person, cooperative or company is eligible for net metering, under certain limitations on installed capacity. Tenants can also access the net metering scheme if the landlord agrees to the installation. The contract ensures a low but stable electricity price over 25 years, regardless of all future price increases. However, the prosumer has the right to end the contract early. The grid operator HEDNO (Hellenic Electricity Distribution Network Operator) meters the electricity generated, as well as all electricity flows to and from the grid every 3 years. The energy netting in the final bill is done by the supplier based on the metering by HEDNO (Law 3583/2014, last modified in 2019 (ΦΕΚ 759Β/2019)), (Σύνδεσμος Εταιριών Φωτοβολταϊκών, 2020).

2. Virtual net metering

Virtual net metering extends previous legislation by allowing the production and consumption of electricity to be spatially disconnected. The consumer can now participate in net metering by installing renewable electricity plants at any location in Greece. This case is especially attractive for prosumers without space for such an installation near their dwelling or for cases where the property owner does not grant permission. In contrast to classic net metering, the prosumer in virtual net metering schemes must pay for all charges and taxes, e.g. grid fees. Only the procurement cost of electricity is saved. Hence, the use of the scheme is only financially profitable when generation costs are below these procurement costs (Law 1547/2017, 2017) (Greek Government, 2017; PHOTOVOLTAIC, 2021).

3. Collective virtual net metering

With the concept of collective virtual net metering, Greece also enabled members of energy communities to use net metering on their collectively owned power plants. Each member owns a share of the electricity generated equivalent to the share of their equity. The share of the electricity generated is accounted for in the energy bill. Members of the community benefit from the collective expertise and the economies of scale, as they share the fixed costs of setting up remote renewable plants. Energy communities can receive funding of up to 40% of their investment costs or a maximum of EUR 1 million.

Since 2020, renewable energy producers have taken on grid-balancing responsibility for their own electricity output in Greece. Producers of renewable energy are now allowed to participate in the wholesale market or are represented by other institutions or companies there.

For renewable energy producers, many of which are small companies, to manage both the complexity of the new market and the balancing costs, the institution ΦΟΣΕ has been established. ΦΟΣΕ comprises 11 companies, many of which are large Greek energy groups that offer to take over such services.

(Greek Parliament, 2018; ecopress, 2019a,b; Electra Energy, 2021)

8
Looking forward: the role of prosumers in an increasingly sustainable energy system

The energy system will continue to evolve in the coming years and decades, as all countries will transition towards a fully sustainable energy system. As the many prosumption initiatives throughout the EU demonstrate, prosumers can play a key part in this development. This requires a supportive policy framework in all countries and continued efforts to increase our understanding of the various aspects of prosumption.

Under the right conditions, the transition to a decarbonised energy system will enable an increasing number of Europe's citizens to actively participate in these developments, much more than in a fossil fuel-based energy system. Citizens can now produce their own energy and provide energy storage or demand flexibility services to the wider energy system, thereby becoming more self-sufficient, reducing their CO_2 footprint and in many cases also reducing their energy costs. Furthermore, research shows that the potential benefits of prosumption go beyond the financial aspects and climate impact. Prosumer projects, most notably in the form of energy cooperatives, are also seen to create social benefits. They are a means for people to engage with their local communities, and actively contribute to and benefit from the ongoing energy transition.

Government policies at all levels — EU, national and local — play a crucial role in these developments. They need to provide the framework in which prosumer projects can be realised effectively and deliver value — both for investors and for the energy system as a whole. EU policies have been adapted over the years to these developments, and the same can be concluded for policies in many countries. However, there is room for improvement in some countries and a need to constantly update the approach in all countries, as the technologies and business models keep improving, the share of energy from renewable sources increases further and the energy demand changes over time.

As shown in this report, citizens have a range of options to get involved and become prosumers. Many different types of prosumers exist, with a wide range of organisational and legal forms, technologies, business models, etc. Prosumer projects can be small, at the level of just one household, or large, such as Som Energía with more than 70,000 members, or anything in between. They can produce renewable energy source (RES) electricity or heat, or both. Since all forms have both benefits and drawbacks, it seems likely that this variety will remain a key part of the future energy system. For most countries, this will be quite a change compared with the energy system of the past, which was largely based on utility-owned and operated power plants, fossil fuels for individual heat appliances and a limited number of refineries supplying the fuel for our cars.

The large variety of prosumer models also creates challenges for policymakers: it is, of course, easier to develop effective policies for a limited number of well-defined models than for a wide range of options. It is also a barrier for monitoring developments and for data collection. As prosumption develops from being a niche solution to becoming the standard, it can challenge the basic tenets of energy system regulation, in particular the conventional utility model and traditional grid-funding mechanism. On the other hand, prosumer solutions hold great potential to contribute to the energy transition, for example by leveraging private capital and by enabling modulation of demand as a way of adjusting to fluctuating RES supply. When devising support and framework conditions for prosumption models, regulators need to take system-wide effects into account and aim to incentivise prosumers to be responsive to system needs while keeping the rules simple enough to permit rapid expansion.

Prosumption is currently still very much in development — the technologies are improving, costs are reducing, and many policies and regulations are still being adapted. However, the trends are going in the right direction, and prosumers are becoming increasingly mainstream in many regions and countries. Despite the growing opportunities for citizens to become prosumers, the role of utilities and other companies in RES production and integration remains significant. They can develop large-scale projects at a low cost per energy unit, which will be key to meeting the future climate goals cost-effectively. We would like to argue that these routes should not be seen as competitors — it is not one or the other. Both have benefits and disadvantages and both are necessary for a robust climate-neutral energy system (EC, 2018). Also, both types of stakeholder can cooperate, as in the case of Compile in Slovenia, for example. The climate targets are very ambitious and all contributions will be necessary to meet them.

8.1 Further actions and research needed

This report is intended for a wide audience that is interested in learning more about the topic, and Chapter 5 describes the way forward for anyone considering becoming a prosumer. However, a number of recommendations for further actions from policymakers and stakeholders also follow from the analysis in this report. The results of these actions can then feed into the policy framework at EU and national levels throughout Europe.

First, it is recommended that policymakers ensure effective implementation of the EU policies related to prosumption, including the existing provisions derived from the 'Clean energy for all Europeans' package and those in the recently proposed REPowerEU communication. This involves not only reducing the regulatory barriers impeding citizens from becoming prosumers, but also implementing stable support policies, and protecting those vulnerable and low-income households that do not have the means to become prosumers from negative financial impacts. Governments can enable future-proofed prosumer solutions by developing key enabling technologies, such as smart meters, and by defining new market roles for prosumers and for facilitators such as aggregators. They can also ensure fair access to the power markets, including a market-based mechanism to incentivise flexibility. Effective carbon pricing in all energy using sectors is another key framework condition for allowing RES-based prosumption to compete with fossil fuels on a level playing field. Regional policymakers and municipalities can support the initiation of energy communities and facilitate co-ownership of generation and transmission assets by regional utilities, energy cooperatives, banks and small and medium sized enterprises.

We also recommend continuing to develop our knowledge of the various aspects of prosumption in Europe. This includes increasing our understanding of:

- the benefits and drawbacks of the various types of prosumption in various situations, looking at all relevant aspects (social impacts, environmental impacts, cost of energy and grid reinforcement, etc.);
- effective policies, organisational models and business models for a given situation;
- the broader impacts of prosumption on the energy system and the means to optimise its impact (through further innovations, system efficiency improvements to reduce the need for grid investments and increase the added value of balancing of the system, ICT and digitalisation solutions for the optimal management of energy storage and demand flexibility, etc.);
- the future contribution of prosumers in the energy system, taking into account the benefits and costs of projects undertaken by both the prosumers and the utilities and other companies;
- mechanisms for ensuring a fair distribution of the costs and benefits of prosumption that protects citizens on low incomes.

Monitoring of prosumption should be developed and implemented to adequately track progress and identify key impacts on society. This requires clear definitions of what should be monitored (the metrics) and a monitoring and reporting obligation at Member State level. As such, the provisions of the Governance Regulation (EU, 2018a) on reporting on prosumers should act only as a baseline for the monitoring plans of Member States. We encourage Member States to go further and develop monitoring plans that are detailed and comprehensive enough to effectively increase knowledge of the aspects of prosumption mentioned above. This is a necessary step to develop fair and effective policies and measures that promote prosumption while minimising the negative impacts and maximising the benefits to the energy system and society.

All stakeholders can support citizens who want to become prosumers by providing information. Governments, businesses active in this field, non-governmental organisations and associations can help by providing specific information relevant to prosumers in a country or region. Examples are prosumer handbooks and websites that explain the relevant policies, regulations and financing options, and provide example of best practice.

Abbreviations

CHP	Combined heat and power
DSO	District system operator
EEA	European Environment Agency
EU	European Union
GHG	Greenhouse gas
RES	Renewable energy source
PV	Photovoltaic
SMEs	Small and medium-sized enterprises
TSO	Transmission system operator

References

Agora Energiewende and Ecologic Institute, 2021, *A "Fit for 55" package based on environmental integrity and solidarity: Designing an EU climate policy architecture for ETS and effort sharing to deliver 55 % lower GHG emissions by 2030,* Agora Energiewende, Berlin.

Artač, G., 2019, *Energy Community Luče* (presentation) (https://www.eem19.eu/wp-content/uploads/2-Energy-Community-Lu%C4%8De.pdf) accessed 19 May 2022.

Banal Estanol, A., 2021, Expert interview 04/06/2021 — Som Energía (interview) 2021.

Blanco, I., et al., 2018, 'Operational planning and bidding for district heating systems with uncertain renewable energy production', *Energies* 11(12), 3310 (DOI: 10.3390/en11123310).

Bódis, K., et al., 2019, 'A high-resolution geospatial assessment of the rooftop solar photovoltaic potential in the European Union', *Renewable and Sustainable Energy Reviews* 114, 109309 (DOI: 10.1016/j.rser.2019.109309).

Brown, D., et al., 2020. *Policies for prosumer business models in the EU: Deliverable 4.2 of the Horizon 2020 PROSEU project,* University of Leeds, Leeds, UK.

Caramizaru, E. and Uihlein, A., 2020, *Energy communities: an overview of energy and social innovation,* Publications Office of the European Union, Luxembourg.

CBS, 2021, 'Lagere energierekening, effecten van lagere prijzen en energiebespaing' (https://www.cbs.nl/nl-nl/longread/rapportages/2021/lagere-energierekening-effecten-van-lagere-prijzen-en-energiebesparing?onepage=true) accessed 4 May 2022.

CE Delft, 2021, *The potential of energy citizens in the European Union,* CE Delft, Delft, Netherlands.

CEER, 2019, *Regulatory aspects of self consumption and energy communities,* Council of European Energy Regulators, Brussels.

Compile, 2019, *Deliverable 2.1 LES: Operational requirements, use cases and KPIs* (https://www.compile-project.eu/wp-content/uploads/COMPILE_D2_1_Operational_requirements_UCs_KPIs_v1_0_FINAL.pdf) accessed 19 May 2022.

Compile, 2020a, *Deliverable 2.3: Regulatory frameworks for energy communities in the pilot site countries Croatia, Spain, Greece, Portugal and Slovenia* (https://www.compile-project.eu/wp-content/uploads/COMPILE_D2_3_Regulatory_frameworks_for_EnC_v1_1.pdf) accessed 19 May 2022.

Compile, 2020b, *Deliverable 4.3: Training program report* (https://www.compile-project.eu/wp-content/uploads/COMPILE_D4_3_Training-Program-Report_v1_0_FINAL.pdf) accessed 19 May 2022.

Compile, 2020c, *Compile pilot sites progress update October 2020* (https://www.compile-project.eu/wp-content/uploads/COMPILE_Brochure_3_Pilot_Sites_Progress_Update_Oct2020.pdf) accessed 19 May 2022.

Compile, 2021, 'Pilot site Luče' (https://www.compile-project.eu/sites/pilot-site-luce/) accessed 4 May 2022.

Dansk Fjernvarme, 2021, 'Danish District Heating Association' (https://www.danskfjernvarme.dk/sitetools/english/about-us) accessed 4 May 2022.

David, A., et al., 2017, 'Heat roadmap Europe: large-scale electric heatpumps in district heating systems', *Energies* 10(4), 578 (DOI: 10.3390/en10040578).

Dehler, J., et al., 2015, *Self-consumption of electricity from renewable sources*, Insight-E, Rapid Response Energy Brief, June, p. 16 (DOI: 10.5445/IR/1000052980).

Doračić, B., et al., 2020, *Proseu Deliverable D5.2. Report on local, national and EU scenarios,* University of Zagreb, Croatia.

EASE, 2022, 'Energy storage — technologies', European Association for Energy Storage (https://ease-storage.eu/energy-storage/technologies/) accessed 9 May 2022.

EC, 2016a, Impact assessment accompanying the document Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (recast) (SWD(2016)0418 final of 30 November 2016).

EC, 2016b, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions and the European Investment Bank 'Clean energy for all Europeans' (COM(2016) 860 final of 30 November 2016).

EC, 2018, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions and the European Investment Bank 'A clean planet for all. A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy' (COM(2018) 773 final of 28 November 2018).

EC, 2020a, *Climate target plan — Stepping up Europe's 2030 climate ambition: Impact assessment part 2,* European Commission, Brussels.

EC, 2020b, *Energy communities in the clean energy package: Best practices and recommendations for implementation,* European Commission, Brussels.

EC, 2021a, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions "'Fit for 55': delivering the EU's 2030 climate target on the way to climate neutrality" (COM(2021)550 of 14 July 2021).

EC, 2021b, Proposal for a Directive of the European Parliament and of the Council on energy efficiency (recast) (COM(2021) 558 final of 14 July 2021).

EC, 2021c, Proposal for a Directive of the European Parliament and of the Council amending Directive (EU) 2018/2001 of the European Parliament and of the Council, Regulation (EU) 2018/1999 of the European Parliament and of the Council and Directive 98/70/EC of the European Parliament and of the Council as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652 (COM(2021) 557 final of 14 July 2021).

EC, 2022a, 'Clean energy for all Europeans package' (https://energy.ec.europa.eu/topics/energy-strategy/clean-energy-all-europeans-package_en) accessed 9 May 2022.

EC, 2022b, 'Energy storage' (https://energy.ec.europa.eu/topics/research-and-technology/energy-storage_en) accessed 9 May 2022.

EC, 2022c, Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions "REPowerEU Plan" (COM(2022) 230 final of 18 May 2022).

ecopress, 2019a, 'Ενεργειακές Κοινότητες: Χρηματοδότηση έως 1 εκατ. ευρώ για έργα ΑΠΕ και ηλεκτροκίνησης' (https://ecopress.gr/energiakes-kinotites-chrimatodoti-2/) accessed 19 May 2022.

ecopress, 2019b, 'Ενεργειακές Κοινότητες: αντιμέτωπες με τον ανταγωνισμό της αγοράς ενέργειας' (https://ecopress.gr/energiakes-kinotites-antimetopes/) accessed 19 May 2022.

EEA, 2020, 'Cross-border cooperation on renewable energy', EEA Briefing No 23/2020, European Environment Agency (https://www.eea.europa.eu/publications/cross-border-cooperation-on-renewable-energy) accessed 12 June 2022.

EEA, 2021a, 'Member States' greenhouse gas (GHG) emission projections', European Environment Agency (https://www.eea.europa.eu/data-and-maps/data/greenhouse-gas-emission-projections-for-8) accessed 21 November 2021.

EEA, 2021b, 'Total greenhouse gas emission trends and projections in Europe', European Environment Agency (https://www.eea.europa.eu/ims/total-greenhouse-gas-emission-trends) accessed 5 May 2022.

EEA, 2022, 'National emissions reported to the UNFCCC and to the EU Greenhouse Gas Monitoring Mechanism', European Environment Agency (https://www.eea.europa.eu/data-and-maps/data/national-emissions-reported-to-the-unfccc-and-to-the-eu-greenhouse-gas-monitoring-mechanism-18) accessed 15 June 2022.

Electra Energy, 2021, 'Hyperion Solar Community: the first collective self-consumption Energy Community in Athens, Greece' (https://electraenergy.coop/here-comes-the-sun-first-community-solar-farm-in-greece/) accessed 5 May 2022.

Energy, V. C., 2020, *Why local solar for all costs less: A new roadmap for the lowest cost grid,* Vibrant Clean Energy, LLC, Boulder, Colorado.

EU, 2018a, Directive (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action (OJ L 328, 21.12.2018, p. 1).

EU, 2018b, Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (OJ L 328, 21.12.2018, p. 82).

EU, 2019, Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (OJ L 158, 14.6.2019, p. 125).

Eurostat, 2022, 'Share of energy from renewable sources' (https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_ren/) accessed 18 June 2022.

Farrell, J., 2016, '*Is bigger best in renewable energy?*' Institute for Local Self-Reliance (https://ilsr.org/report-is-bigger-best/) accessed 19 May 2022.

Fleischhacker, A., et al., 2018, *Improvement of PVP4GRID concepts: D3.1 public deliverable* (https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5bfbf7e1f&appId=PPGMS) accessed 19 May 2022.

FLEXCoop, 2020, *Emerging business models, associated DR strategies and standard contracts templates — Final Version* (https://www.rescoop.eu/uploads/rescoop/downloads/D2.7-FLEXCoop-Emerging-Business-Models-Final-version-v.1.5.docx.pdf) accessed 19 May 2022.

Fraunhofer ISI, Consentec, ifeu, 2017, *Langfristszenarien für die Transformation des Energiesystems in Deutschland* (https://www.isi.fraunhofer.de/content/dam/isi/dokumente/ccx/2021/LFS_Kurzbericht.pdf) accessed 21 June 2022.

Gasunie, 2022, 'Hydrogen backbone' (https://www.gasunie.nl/en/expertise/hydrogen/hydrogen-backbone) accessed 9 May 2022.

Generation kWh, 2021, 'Bienvenido/a a la generación kWh' (https://www.generationkwh.org/) accessed 5 May 2022.

GfK Belgium Consortium, 2017, *Study on "Residential Prosumers in the European Energy Union",* (https://ec.europa.eu/info/sites/default/files/study-residential-prosumers-energy-union_en.pdf) accessed 19 May 2022.

Good, N., et al., 2017, 'Review and classification of barriers and enablers of demand response in the smart grid', *Renewable and Sustainable Energy Reviews* 72, pp. 57-72.

Gorroño-Albizu, L., 2020, 'The benefits of local cross-sector consumer ownership models for the transition to a renewable smart energy system in Denmark. An exploratory study', *Energies* 13(6), 1508 (DOI: 10.3390/en13061508).

Gorroño-Albizu, L., et al., 2019, 'The past, present and uncertain future of community energy in Denmark: critically reviewing and conceptualising citizen ownership', *Energy Research & Social Science* 57, 101231 (DOI: 10.1016/j.erss.2019.101231).

Greek Government, 2017, Ministerial Decision No. APEIL/A/F1/oik. 175067/2017: Installation of photovoltaic power plants by self-producers with application of net-metering or virtual net-metering according to article 14A of Law No. 3468/2006, as in force (https://www.e-nomothesia.gr/energeia/upourgike-apophase-apeelaph1-oik-175067-2017.html) accessed 19 May 2022.

Greek Parliament, 2018, Law 4513/2018: Energy communities and other provisions, *Governmental Gazette,* Issue 9/23-01-2018.

Gsänger, S. and Karl, T., 2019, *Bürgerwind im Ausschreibungsmodell. Eine Bilanz,* World Wind Energy Association, Bonn, Germany, and Landesverband Erneuerbare Energien Nordrhein-Westfalen, Düsseldorf, Germany.

Hall, S., et al., 2020, *Prosumers for the Energy Union: Mainstreaming active participation of citizens in the energy transition — Business models for prosumers in Europe,* University of Leeds, Leeds, UK.

Hier opgewekt, 2021, 'Lokale Energie Monitor 2020: Een jaarlijkse rapportage en analyse van de ontwikkelingen van de burgerenergie-initiatieven in Nederland' (https://www.hieropgewekt.nl/lokale-energie-monitor) accessed 5 May 2022.

Horstink, L., et al., 2019, *PROSEU-Prosumers for the Energy Union: Mainstreaming active participation of citizens in the energy transition, Review and characterisation of collective renewable energy prosumer initiatives (Deliverable No 2.1), Horizon 2020 (H2020-LCE-2017)* https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5c415f172&appId=PPGMS) accessed 19 May 2022.

Hvide Sande Fjernvarme, 2021, 'Årsrapport 2020' (https://www.hsfv.dk/media/43970/aarsrapport-2020.pdf) accessed 17 June 2022.

Kelm, T., et al., 2019, *Vorbereitung und Begleitung bei der Erstellung eines Erfahrungsberichts gemäß § 97 Erneuerbare-Energien-Gesetz. Teilvorhaben II,* Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW), Stuttgart, Germany and Bosch and Partner, Hannover, Germany.

Laes, E., et al., 2019, 'Diagnosing barriers and enablers for the Flemish energy transition', *Sustainability* 11(20), 5558 (DOI: 10.3390/su11205558).

Lowitzsch, J., 2019, *Energy transition — Financing consumer co-ownership in renewables,* Palgrave Macmillan, Cham, Switzerland.

Maleki-Dizaji, P., et al., 2020, 'Overcoming barriers to the community acceptance of wind energy: Lessons learnt from a comparative analysis of best practice cases across Europe', *Sustainability* 12(9), 3562 (DOI: 10.3390/su12093562).

mp energy, 2021, *'Net metering'* (https://www.mp-energy.gr/%CE%B1%CF%85%CF%84%CE%BF%CF%80%CE%B1%CF%81%CE%B1%CE%B3%CF%89%CE%B3%CE%B7-%CE%B5%CE%BD%CE%B5%CF%81%CE%B3%CE%B5%CE%B9%CE%B1%CF%83/net-metering.html) accessed 5 May 2022.

Paardekooper, S., et al., 2018, *Heat roadmap Europe 4: Quantifying the impact of low-carbon heating and cooling roadmaps* (https://vbn.aau.dk/en/publications/heat-roadmap-europe-4-quantifying-the-impact-of-low-carbon-heatin) accessed 19 May 2022.

Pellicer-Sifres, V., et al., 2018, 'Learning, transformative action, and grassroots innovation: insights from the Spanish energy cooperative Som Energia', *Energy Research & Social Science,* 42, pp. 100-111.

Petrick, K., et al., 2019a, *Prosumers for the Energy Union: Mainstreaming active participation of citizens in the energy transition — Strategies for policy coherence and sustainability (D3.2), part 2* (https://zenodo.org/record/3584810#.YOxOf_JxeM8) accessed 19 May 2022.

Petrick, K., et al., 2019b, *Prosumers for the Energy Union: Mainstreaming active participation of citizens in the energy transition — Strategies for policy coherence and sustainability (D3.2), part 1* (https://zenodo.org/record/3584774#.YP6_68RxeUk) accessed 5 May 2022.

PHOTOVOLTAIC, 2021, 'Virtual net metering: Συχνές Ερωτήσεις — Απαντήσεις [Questions and answers]' (https://www.photovoltaic.gr/en/company/press-releases/law-branch/virtual-net-metering.html) accessed 5 May 2022.

Protergia, 2021, 'Protergia net metering — Συχνές Ερωτήσεις', (https://www.protergia.gr/el/protergia-net-metering-syxnes-erwthseis) accessed 5 May 2022.

PVP4Grid, 2020a, 'Guidelines & policy papers' (https://www.pvp4grid.eu/guidelines-policy-papers/ accessed 2021.

PVP4Grid, 2020b, *D4.2 Impacts of PVP concepts on grid system, Summary Report* (https://www.pvp4grid.eu/wp-content/uploads/2020/04/PVP4Grid_D4.2_Summary-report_EU_200330.pdf) accessed 20 June 2022.

RAP, 2021, *Energy communities with grid benefits — A quest for a blueprint',* Regulatory Assistance Project (https://www.raponline.org/wp-content/uploads/2020/12/rap-community-energy-January-2021.pdf) accessed 5 May 2022.

Res Legal Europe, 2019, '*Legal sources on renewable energy — Spain: Summary*' (http://www.res-legal.eu/search-by-country/spain/summary/c/spain/s/res-e/sum/196/lpid/195/) accessed 19 May 2022.

REScoop MECISE consortium, 2018, *REScoop — Mobilising European citizens to invest in sustainable energy — Deliverable D1.3, Progress report 6, month 39-44,* Ecopower cvba, Berchem, Belgium.

REScoop MECISE, 2019, *Mobilising European citizens to invest in sustainable energy — Clean Energy for all Europeans: Final results oriented report of the RESCOOP MECISE Horizon 2020 Project* (https://www.rescoop.eu/uploads/Moblising-European-Citizens-to-Invest-in-Sustainable-Energy.pdf) accessed 19 May 2022.

REScoop, 2022, 'REScoop is the the European federation of citizen energy projects', (https://www.rescoop.eu) accessed 5 May 2022.

Roberts, J., et al., 2019, *Compile: Integrating community power in energy islands: Energy community definitions* (https://www.compile-project.eu/wp-content/uploads/Explanatory-note-on-energy-community-definitions.pdf) accessed 19 May 2022.

Schoonschip, 2018, 'Stichting Doen helpt Schoonschip kennis te delen' (https://schoonschipamsterdam.org/2018/06/08/stichting-doen-helpt-schoonschip-kennis-te-delen/) accessed 19 May 2022.

Schoonschip, 2021a, 'Introduction Schoonschip' (https://greenprint.schoonschipamsterdam.org/impactgebieden/introductie) accessed 5 May 2022.

Schoonschip, 2021b, 'Legal' (https://greenprint.schoonschipamsterdam.org/impactgebieden/juridisch) accessed 20 June 2022.

Schoonschip, 2021c, 'Social and Governance' (https://greenprint.schoonschipamsterdam.org/impactgebieden/sociaal) accessed 5 May 2022.

Schoonschip, 2021d, 'Energy' (https://greenprint.schoonschipamsterdam.org/impactgebieden/energie) accessed 20 June 2022.

smartEn, 2020, 'The smartEnMap 2020 — prosumers', Smart Energy Europe (https://smarten.eu/the-smarten-map-2020-prosumers/) accessed 5 May 2022.

Som Energía, 2018, 'Com ens afecta el Reial Decret per a la transició energètica', Blog (https://blog.somenergia.coop/tarifas-electricidad-y-sector-electrico/2018/11/com-ens-afecta-el-nou-reial-decret-per-a-la-transicio-energetica/) accessed 19 May 2022.

Som Energía, 2021a, 'Condiciones generals de les aportacions voluntàries al capitala social' (https://www.somenergia.coop/ca/condicions-generals-aportacio/) accessed 5 May 2022.

Som Energía, 2021b, 'Som Energia denuncia que el mecanismo de subasta del régimen económico de energías renovables deja fuera comunidades energéticas y proyectos pequeños', Blog (https://blog.somenergia.coop/etiqueta/subasta/) accessed 5 May 2022.

Som Energía, 2021c, 'How does simplified surplus compensation work?' (https://ca.support.somenergia.coop/article/783-com-funciona-la-compensacio-simplificada-dexcedents) accessed 5 May 2022.

Som Energía, 2022, 'Memoria social y económica 2021' (https://drive.google.com/file/d/1Oo1aqs9eRourKUkJtdXOvwASBs_DrMdK/view) accessed 21 June 2022.

Sustainable Energy Authority of Ireland, 2021, 'Renewable Electricity Support Scheme (RESS)' (https://www.seai.ie/community-energy/ress/) accessed 28 July 2021.

Toporek, M. and Campos, I., 2019, *Prosumers for the Energy Union: Mainstreaming active participation of citizens in the energy transition. Assessment of existing EU-wide and Member State-specific regulatory and policy frameworks of RES prosumers (Deliverable N°3.1),* CLIENTEARTH (https://proseu.eu/sites/default/files/Resources/PROSEU_%20D3.1RegulatoryFrameworksRES_Prosumers.pdf) accessed 22 June 2022.

Umpfenbach, K. and Faber, R., 2021, *StromNachbarn: Evaluation der sozialen und* ökologischen *Wirkungen von Mieterstromanlagen in Berlin,* Ecornet Berlin, Berlin.

UNFCCC, 2015, Paris Agreement, United Nations Framework Convention on Climate Change, Bonn, Germany.

URE, 2022, Raport dotyczący energii elektrycznej wytworzonej z OZE w mikroinstalacji i wprowadzonej do sieci dystrybucyjnej w 2021 (https://bip.ure.gov.pl/download/3/14774/RAPORT-ENERGIAELEKTRYCZNAWYTWORZONAWOZEWMIKROINSTALACJIW2021R.pdf) accessed 17 June 2022.

Wierling, A. ,et al., 2018, 'Statistical evidence on the role of energy cooperatives for the energy transition in European countries', *Sustainability* 10(9), 3339 (DOI: 10.3390/su10093339).

Winkler, J., et al., 2014, *Eigenversorgung mit Strom: Analyse der Wirkungen und Szenarien für die zukünftige Entwicklung,* Bundesministeriums für Wirtschaft und Energie, Berlin.

Σύνδεσμος Εταιριών Φωτοβολταϊκών, 2020, *Net-metering — Αυτοπαραγωγή με ενεργειακό συμψηφισμό και εικονικό ενεργειακό συμψηφισμό για ιδιώτες, επιχειρήσεις και ενεργειακές κοινότητες με ή χωρίς αποθήκευση* (https://helapco.gr/pdf/HELAPCO_Net_Metering.pdf) accessed 5 May 2022.

European Environment Agency

Energy Prosumers in Europe - Citizen participation in the energy transition

2022 — 57 pp. — 21 x 29.7 cm

ISBN: 978-92-9480-472-3
doi:10.2800/030218

TH-AL-22-002-EN-N
doi:10.2800/030218

European Environment Agency
Kongens Nytorv 6
1050 Copenhagen K
Denmark
Tel.: +45 33 36 71 00
Web: eea.europa.eu
Enquiries: eea.europa.eu/enquiries

Publications Office
of the European Union