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Table of contents

0 Executive Summary

The SERENE project strives for integrated local energy systems that are decentralized, digitalized and much more citizen-centered than current energy systems. These energy systems do not neatly fit into today's policies, regulations and rules, which were designed for more centralized energy systems characterized by large-scale energy providers. This report (SERENE project deliverable 3.1) therefore considers the non-technological dynamics of energy transitions which might play a role for the implementation of the SERENE project. Specifically, it addresses the question: *Which socio-economic, governance and regulatory factors influence the local energy system transition?*

In this report, we consider the energy system as a socio-technical system comprising both technological and social components, and energy system transitions as socio-technical transitions in which technological and social components co-evolve. Conceptually, this analysis is rooted in the socio-technical system change and transition management literature.

The report is the result of a three-step process (Figure 0.1). First, we identify general social factors that influence socio-technical transitions in local energy systems based on extensive literature reviews from six different social science perspectives: 1) socio-economics, 2) regulations, 3) governance, 4) urban planning, 5) social acceptance, and 6) societal debates. Second, we relate these general factors to the characteristics of the different SERENE demonstrator sites in Denmark, the Netherlands and Poland, drawing from SERENE project documents, policy reports and key actor input during project meetings, focus groups and interviews. Third, we specify areas in need of attention during the implementation of

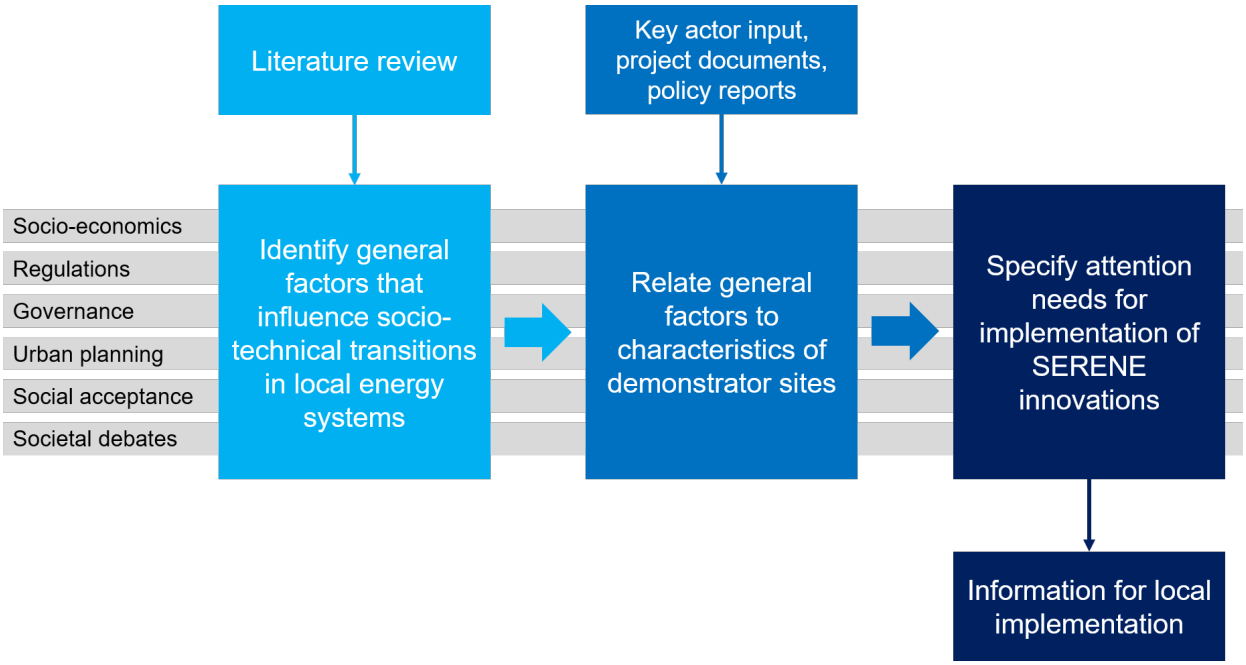

Figure 0.1. Three-step process to identify socio-economic, governance and regulatory factors that influence the local energy system transition in the SERENE demonstrators.

SERENE activities in the demonstrator sites that can inform the work of local implementation partners, and opportunities for SERENE to provide new knowledge on social dynamics in local energy system transitions. We provide a brief summary of the key results of this process below.

Socio-economic factors, including the personal circumstances and motives of individual citizens and the interactions between technology and the energy market, influence energy consumption patterns and can create incentives for investments in the local energy system. With regards to the SERENE demonstrators, a broad community survey will be needed to capture the individual socio-economic circumstances and motivations of local residents. The SERENE project implementation will be influenced by the different economic and non-economic incentives in the local contexts and by potential paradigm shifts sparked by technological or social interventions. Project activities also need to be sensitive to local energy poverty conditions and avoid increasing local vulnerabilities.

Regulatory factors are predominantly related to the mismatch between the existing regulations, which were originally designed for fossil fuel-based energy systems, and the regulations needed to facilitate local energy systems based on renewable energy sources, including corresponding market regulations. The incomplete transposition of the new EU energy directives is creating significant regulatory uncertainty in the demonstrators, as the specific conditions for energy communities and their implications for the SERENE project implementation are yet to be determined. At the same time, it is already clear that interventions will need to address a wide range of regulatory issues related to their specific technological or social innovations, and related to broader regulations like the right of EU citizens to choose their energy supplier. The Dutch and Polish demonstrators provide some opportunities for experimentation, as they both enjoy some degree of exemptions from energy laws, giving them a 'regulatory sandbox' status.

Governance factors cover a range of factors related to the polycentric nature of energy governance, with transition processes including various institutions and actors across different levels, each of which may influence the local energy system transition. It is therefore crucial to account for the role of different actors and institutions in the energy transition processes in each demonstrator, and to reflect on whether their role matches their position within the SERENE project. Implementation partners additionally need to ensure opportunities for the active participation of local residents, and account for emerging self-organization structures and the heterogeneous energy visions and preferences of the local community and actors.

Urban planning factors revolve around the decentralized local energy system as a new contender for urban land use, and the need to integrate energy and urban planning in multi-sectoral and multi-objective considerations. The current energy infrastructure capacity and mobility patterns in the demonstrators influence potential trajectories for the expansion of local renewable energy generation and electric mobility, which are part of the planned SERENE interventions in all demo sites. Project implementation should capitalize on urban commoning potential where it is available (Dutch demonstrators), and help create potential where it is lacking (Danish and Polish demonstrators), to ensure bottom-up, adaptive urban and energy planning.

Social acceptance factors, related to people's perceptions, attitudes, and thoughts towards a social transformation of energy, determine likely positive or negative community reactions to the local energy system transformation. Prior experiences with decentralized, renewable energy generation and the overall environmental awareness in the demonstrators have created various levels of expected social acceptance and attitudes towards the SERENE project. More detailed insights based on individual-level acceptance will need to be gathered with a community survey. Throughout the project, implementation partners need to be mindful of and, where possible, capitalize on changes in social acceptance through community movements or in reaction to specific interventions.

Societal debate factors reflect on the changing role of citizens in the local energy system transition and cover issues related to notions of discourse, socio-technical imaginary and citizen empowerment. The demonstrators start out in different places with regards to existing social organization on energy and other issues, as well as with regards to the on-going energy and sustainability discourses within the local communities. It will be important to assess how these discourses change throughout the SERENE project, both organically and due to social interventions that aim to open spaces for new local energy debates.

The most important implications of each set of social factors for the SERENE project and for the implementation of different innovations related to the local energy system transition in the demonstrators are summarized in Table 0.1.

The different factors identified in this deliverable can present obstacles to the implementation of specific technical or social innovations or to the overall local energy transition, as well as lead to unintended side effects of innovations, e.g., the marginalization of vulnerable groups. A follow-up to this report, SERENE project deliverable 3.2, builds on our analysis to assess the obstacles related to these factors in more detail.

Table 0.1. Summary of the most important implications for the SERENE project and implementation processes in the demonstrators for each social science perspective.

Social science perspective	Key implications for demonstrators and SERENE project
Socio-economics	• Community survey needed for data on individual socio-economic circumstances and motivations of local residents • Presence or absence of different incentives for energy transition • Local energy poverty conditions and vulnerabilities • Opportunities for paradigm shifts on local energy use
Regulations	• Regulatory uncertainty due to incomplete transposition of EU energy directives • Right of EU citizens to choose their energy supplier • Opportunities linked to 'regulatory sandboxes' in Dutch and Polish demonstrators • Specific regulatory conditions linked to individual interventions and actors
Governance	• Role of different actors and institutions in the local energy transition processes in the demonstrators, and match between this role and their position in SERENE

	• Emerging self-organization within the community • Opportunities for active participation of local residents • Heterogeneous energy visions and preferences throughout project implementation
Urban planning	• Capacity of current local energy infrastructure • Expansion of electric mobility • Urban commoning potential and trajectories throughout project implementation
Social acceptance	• Prior experiences and acceptance patterns in the demonstrators • Changes to social acceptance through interventions or community movements throughout project implementation • Insights on individual-level acceptance require community survey
Societal debates	• Social organization in the demonstrators on energy and other issues • Role of current energy and sustainability discourses for project implementation • Influence of SERENE interventions on local energy discourses and debates

1 Introduction and objectives

The SERENE project strives for integrated local energy systems that are decentralized, digitalized and much more citizen-centered than current energy systems. These energy systems do not neatly fit into today's policies, regulations and rules, which were designed for more centralized energy systems characterized by large-scale energy providers. Challenges to the envisioned system transition therefore do not only lie in technological barriers of the current energy system, but also in non-technical barriers associated with social, economic and environmental obstacles.

At the same time, the transition of energy systems also entails much more than technological system change. It is useful to instead consider the energy system as a socio-technical system, which includes both technical components (e.g., physical infrastructure and hardware) and social components (e.g., actors and institutions). Transitions of socio-technical systems then involve the co-evolution of technological components, institutions, business models and user practices (Schot & Geels, 2008; Verbong & Geels, 2012). We thus need to study the socio-economic, governance and regulatory factors that influence the energy system, in order to gain a deeper understanding of the non-technological dynamics of the transitions.

The SERENE project specifically focuses on *local* energy system transitions. This is based on the importance of the local level in sustainable transitions in general and in the energy transition in particular. Since the Earth Summit in Rio in 1992, there has been growing attention to activities on the local level, as local communities are well-placed to identify specific local energy needs, and to take action and bring actors together to achieve common energy goals, facilitate stakeholder involvement and encourage public participation (Broto, 2017; Eckersley, 2018). As the level of governance closest to the people, initiatives on the local level can also help to overcome the gap between national or international policy goals and their implementation (Broto, 2017; Jänicke & Quitzow, 2017). Accordingly, the EU has put increasing focus on the role of the local systems in the energy transition (European Commission [EC], 2020).

In order to fully understand local energy system transitions and to successfully implement interventions that can push the local energy system in the envisioned direction, it is thus important to account for social processes and their effect on other transition dynamics. Consequently, this report (SERENE project deliverable 3.1) addresses the question: *Which socio-economic, governance and regulatory factors influence the local energy system transition?* It provides a baseline on the social conditions in the different SERENE demonstrator sites and identifies relevant topics for further study throughout the project. It also lays the groundwork for a follow-up report (SERENE project deliverable 3.2), which assess in how far these factors are potential obstacles for the local energy system transition in SERENE.

This report is the result of a three-step process (Figure 1.1). First, we identify general social factors that influence socio-technical transitions in local energy systems based on literature reviews from six different social science perspectives: (1) socio-economics, (2) regulations, (3) governance, (4) urban planning, (5) social acceptance, and (6) societal debates. Each of these perspectives offers unique insights on social factors and dynamics surrounding local energy system transitions. Second, we relate these general factors to the characteristics of the different SERENE demonstrator sites, drawing from SERENE project

documents, policy reports and key actor input during project meetings, focus groups and interviews. Third, we specify areas in need of attention during the implementation of SERENE activities in the demonstrator sites. This provides project partners with information relevant to the local implementation of interventions, and identifies opportunities for SERENE to provide new knowledge on social dynamics in local energy system transitions.

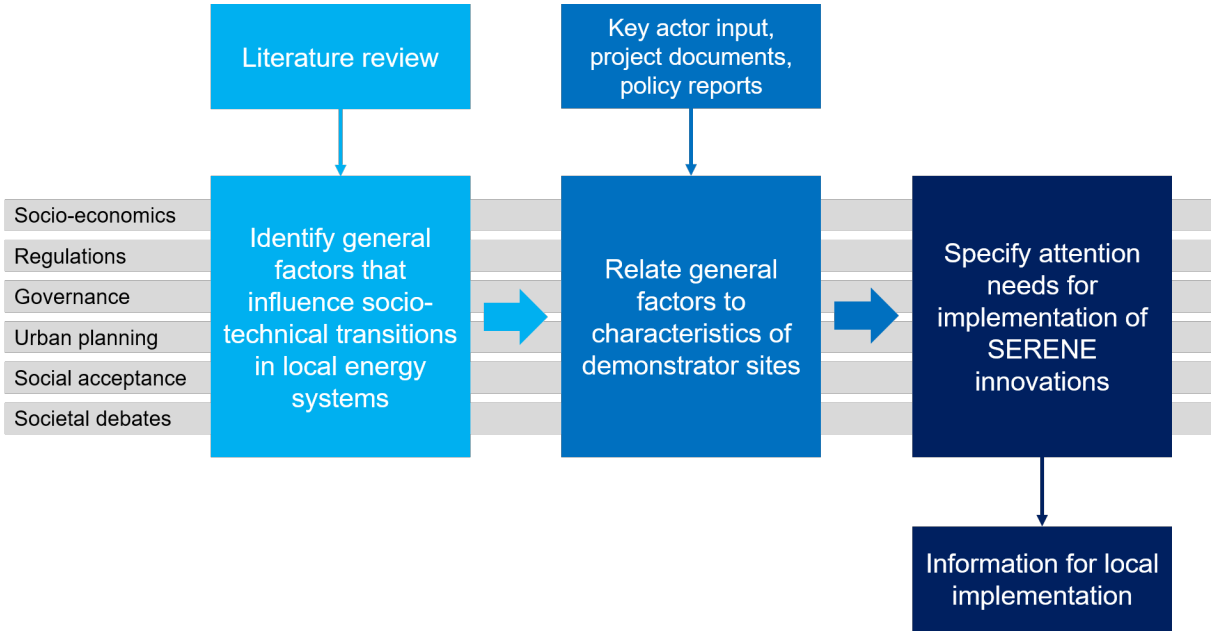

Figure 1.1. Three-step process to identify socio-economic, governance and regulatory factors that influence the local energy system transition in the SERENE demonstrators.

The remainder of this report is structured as follows: *Section 2* defines several key terms related to the local energy system transition. *Section 3* introduces the SERENE project and its demonstrators, and relates it to common trends and challenges in the energy transition. *Section 4* more broadly discuss system change and energy transitions from a transition literature perspective. *Section 5*, which is the main contribution of this report, addresses the influence of various social factors on local energy system transitions in general and outlines relevant conditions in the SERENE demonstrators. *Section 6* provides a concluding summary and outlines common denominators and linkages between the factors and their implications for the SERENE project.

2 Key definitions

2.1 Energy transitions

Countless studies in the past couple of decades have contributed to the field of energy transitions, with some new journals dedicated to the issue of energy transitions, such as Energy Research & Social Science. Consequently, the definitions of energy transitions have become somewhat intentionally broad and there is no one concrete definition that would provide a full and holistic picture of the concept. Nevertheless, Sovacool (2016) showed that there are some of the shared key terms such as "change in fuels," "shifts in fuel source for energy production," "fuel technologies," "significant changes to the patterns of energy use," "series of energy sources," and "production of new primary energy source" (Sovacool, 2016, p. 203). Similarly, Araujo argued that contemporary energy transitions are characterized by "urgency," "trade offs," and "innovation" (Araújo, 2014, p. 113).

Furthermore, as the term "transition" suggests, there is a component of temporality – it takes time to change from one energy system or source to an alternative energy system or source that meets the demands of the market, consumers, producers, and other stakeholders. The understanding of temporality is discussed in depth in Fouquet's (2016) article on speed, prices of energy transitions. Fouquet (2016) found that energy transitions often take an opportunistic approach by finding and using energy sources that are cheaper, widely available, or meet specific demands of the users, e.g., sustainability (Sovacool, 2016). In this sense, although many contemporary energy transition movements tend to focus on more sustainable energy systems and sources, historical energy transitions have not always moved towards sustainability.

A few studies argue that the energy transitions in the past are distinctively different from the energy transitions that we are currently going through (Kern & Rogge, 2016; Sovacool, 2016). The contemporary energy transitions are expected to be quicker, due to the global consciousness towards sustainability governance as well as multidimensional involvement from a wide variety of stakeholders and actors. Kern and Rogge (2016) claim that the 2015 Paris Agreement is the epitome of a global commitment and political will towards sustainable energy transitions.

2.2 Energy decentralization

Energy decentralization is one of the most popular forms of energy transitions discussed in the literature. Energy decentralization moves away from having a few central, large-scale producers and service providers, e.g., energy companies and electricity distributors, towards a system with numerous small-scale providers that produce, procure, distribute, and sell energy to smaller groups of customers. Goldthau (2014) argues that decentralized systems can offer significant benefits over centralized systems, such as increased energy efficiency, increased independence and energy security, and a greater share of renewable energies.

There are varying types of energy decentralization. One method that is gaining traction is blockchain-based energy decentralization. Decentralizing the markets for energy by including relevant stakeholders to be producers, sellers, and consumers of energy has opened up many doors for the future of energy decentralization (Pop et al., 2018). Another paragon of energy decentralization is microgrid networks, which potentially allow their users to be completely disconnected from the main grid (Carli & Dotoli, 2019).

McKenna (2018) stated that community energy is one of the key concepts in the operationalization of energy decentralization. Several studies share this line of thinking and support community-level autonomy in energy decentralization (Bauwens, Gotchev, & Holstenkamp, 2016; Hess & Lee, 2020; Hewitt et al., 2019; Oteman, Wiering, & Helderman, 2014). This also overlaps with the concept of energy communities, which is a core component of the EU's energy transition strategy and further explained in Section 2.5.

2.3 Energy users

Throughout our analysis of social dynamics and the socio-economic, governance and regulatory factors that influence the local energy system transition, energy users may fill one of three key roles that we briefly introduce below. Over the course of the transition towards decentralized, renewables-based energy systems, the role of different energy users within the system and the way in which they interact with the system and each other will change. The range of factors influencing this change are further explored in Section 5.

Users as consumers

Users who are part of the energy network and use it solely to purchase and use energy, are presenting the role of users as consumers. A consumer can generally be defined as an individual or group of end-users who use a product, service or infrastructure to satisfy their desires, needs or preferences (Bogers, Afuah, & Bastian, 2010, p. 857). While it might appear as if consumers are not actively contributing to the structural changes and overall character of the network, they are indeed influencing the system to a certain extent. On the one hand, through their usage of the network structure, consumers are indirectly upholding the current structure of the system and appropriating the use of the energy exchange platform in general. On the other hand, technological advancements have given consumers a range of new tools to monitor and control their own consumption, including reacting to price spikes by reducing energy use. The increasing variety of energy providers has also given consumers new choices, e.g., enabling them to actively choose green energy over fossil fuel-based energy. In this way, consumers are given more agency and will be able to play a more active role in future energy systems.

Users as producers

Users of the network can, apart from using the structures, provide the network with energy that they have produced in their own households and directly partake in the network as nodes. By providing energy

to the network, individual users change their relationship to the network and their role from being consumers towards becoming producers. As such, they do not use the energy system to satisfy their own energy needs, but rather to obtain rewards or compensation for their contribution to the network out of economic interest (Antonopoulos, 2014, p. 177; Bitcoin Energy Consumption Index, 2019; Conoscenti, Vetrò, & De Martin, 2016, p. 2). Such producers are often commercial operations of significant size, and subject to various grid and market regulations. Small-scale, private users who produce energy are often also using this energy or energy from the grid to cover their own needs, putting them in the category of prosumers as further explained below.

Producers are actively partaking in the system, shaping the networks' structure, development and transformation in the long-run and co-constitute the network through their endeavours and through providing the basic structure which is used by consumers. Furthermore, this role shift is visible in the emerging practices of users orientating the form of their participation in the network towards a more economically focused perspective by increasing the number of nodes they operate and increasing the energy/power they provide to the network. This does not only increase the requirements of technical knowledge and investments from users oriented to become producers in the network, but also gives rise to new sets of innovative possibilities and forms of cooperation. Through combining technical knowledge with the increasing demand for power to remain competitive as a producer in the network, users become innovative and may start using advanced hardware. Furthermore, such a change in the role of producers towards requiring increased technical knowledge and innovation, as well as the capacity to obtain advanced hardware, solidifies the boundaries between being a consumer and becoming a producer in the system (Bogers et al., 2010, p. 860; Taylor, 2017, p. 62).

Users as prosumers

Apart from the role of consumer and producer, users might take a third role in novel peer-to-peer energy infrastructures: the role of prosumer. The role of the prosumer can be defined as a hybrid, indicating the novel form of users simultaneously playing the role of producers and consumers, and blurring the distinction between those two roles (Humphreys & Grayson, 2008). Prosumers typically first use their produced energy to cover their own demands at the time, and provide the remaining energy to the applicable grid. A study of Finnish energy prosumers found that in the case of infrastructures for local energy sharing and trading, users in the role of prosumers are most likely using the economic rewards they have obtained through their contribution of power to the system to buy energy themselves or save the money, similar to consumers in the network. They are making use of a structure they have contributed to and have constituted as producers, facilitating their transactions as consumers. The lines between the two roles of consumer and producer thus dissolve in these cases and are merged within the role of the prosumer (Olkkonen, Korjonen-Kuusipuro, & Grönberg, 2017).

2.4 Energy markets

Several key issues with the operation of the energy system and its transition envisioned in SERENE lie with the energy market, in particular the electricity market. The supply chain of electricity generation and

supply are market activities. Market activities follow market rules, but they are regulated. If we want to understand necessary changes for introducing renewables in the local energy system and changes needed for smart grids, we need to look at market organization activities and their regulation like unbundling of activities and responsible actors, and rules for selling energy and peer-to-peer supply. In order to understand the necessary changes and the obstacles, we first discuss the (economic) organization of energy markets, in particular electricity markets.

Energy markets are commodity markets that deal specifically with the trade and supply of energy, including both fossil fuels and renewable energy sources, as well as the energy generated from them. Electricity is a special commodity in this context, with consequences for economic market ordering and regulation:

- There must always be a balance between electricity generation and consumption.
- Transportation and distribution are performed on a power network with specific physical rules.
- Electricity storage is uneconomical (as of today).
- A large part of the electric demand is of must-serve nature (residential, hospitals, etc.).
- The final consumers cannot really determine the origin of the product (i.e., the electricity received from the grid), its quality or nature.

If we look back in history, it is clear that technology determines (economic) organization of the electricity market. Based on economy of scale and physical rules, an electricity market was built up with some logical characteristics, including economies of scale with large generation units; generation units near load centers; high voltage lines for electricity transmission; interconnection of plants to optimize on different characteristics (natural resources), including lowering the need for costly reserve capacity; interconnection loads to optimize on diversity in demand; central coordination in technical and economical dispatch; and offering low and differentiated rates to cultivate mass consumption (supply creates demand).

The economic perspective also influenced the technological components of the energy systems. The reason that the electricity market was established as a large integrated technological system has to do with costs: many assets in the fossil fuel-based electricity system are specific technologies that are only relevant for the electricity system. From an economic perspective, this creates problems related to the mitigation of financial risks for investors, because many assets require substantial upfront investments. Economy of scale is an important risk mitigator, leading to a natural grid monopoly. Electricity additionally has a low price elasticity, as there is no substitution product consumers could switch to in case of price increase. Furthermore, electricity cannot easily be stored, although this is changing. Combined, this means that there is the danger of monopolies setting high prices for consumers. Governments have a strong interest in guaranteeing security and reliability of electricity supply and a fair price that reflects suppliers' costs and investments with a reasonable profit margin. This is where monopoly and price regulations in the electricity market came into play.

If we talk about markets, we must think about retail and wholesale markets. Retail refers to the activity of selling goods or services directly to consumers or end-users. The wholesale market is the market for the sale of goods to a retailer, meaning a wholesaler receives large quantities of goods from a

manufacturer and distributes them to stores, where they are sold to consumers. A wholesaler is generally able to extract a better price from the manufacturer due to the large quantity, enabling them, in theory, to sell the goods at a better price for the consumer due to economies of scale.

To understand different factors at play in the electricity market, we need to look at how it was and still is organized in large parts of the world. In the following, we briefly outline monopolies and market liberalization as two key dynamics in these markets.

Monopoly

The vertically integrated monopoly market typically comprises a natural monopoly regulation with centralized planning, management and control of capacity of energy production with tariffs set by public owned vertically integrated companies, who integrate production, transmission, distribution, and supply in one organization. While there are nowadays EU-wide regulations against bundling these operations within one company, such monopolies are part of the history of European energy markets and still common in other parts of the world.

In the operation of the vertically integrated company, prices are based on fixed costs (investments, continuation of the company) plus variable costs (fuel and staff). Electricity prices for electricity provided by vertically integrated companies under monopoly regulation are also determined by social considerations and factors such as subsidies. Prices on average cost-based rates are determined by regulation, which means that energy companies can operate their power plants profitably, and, in the long term, take feasible decisions on investments. This, however, does not mean that the established prices are as low as possible from a market perspective of supply and demand. This is how liberalization came into play.

Liberalization

Liberalization is an institutional reform that turned the major organizations from monopoly to market organizations. At the same time, it led to a process of privatization – from public to private ownership of market actors. However, liberalization does not mean complete deregulation. Government functions as market regulator from a distance.

In a regulated energy market, transmission and distribution prices are set by regulatory or government bodies, while in a deregulated market, prices are determined by the invisible hand of the market (competitive prices). Regulation can limit the choices available to companies on competitive markets: e.g., their ability to set prices, quantities, and terms of supply without interference, their ability to choose their contractual partners, and their freedom to make certain investments (or not). Regulation in the electricity sector often limits these choices, for instance by regulating prices (e.g., feed-in tariffs) and service conditions (e.g., security of supply), imposing universal service obligations and market access obligations (thus limiting the choice of contractual partners), imposing mandatory terms and conditions (e.g., specific consumer rights and terms of supplying competitors), as well as setting requirements for investment (or penalizing decisions to under-invest, e.g., with competition law).

Important elements of a regulated, liberalized energy market are: a free choice of supplier for consumers; no entry restrictions for production and supply creating competition between market actors; no tariff restriction in production and supply; unbundling of commercial and transportation functions in the energy chain; and third-party access to the grid.

The objective of the liberalized Internal European Energy market was to achieve security of supply, competitive prices and enhanced services to customers. For this, although capacity and sources of electricity generation are left to market forces, some minimum governmental oversight and regulation remains necessary to ensure security of supply and sustainability (Erlinghagen, Lichtensteiger, & Markard, 2015).

Market actors

To understand how socio-economic, governance and regulation factors influence the local energy system transition, the regulated roles of traditional actors in the electricity market system are important. The first category of market players are those who operate the power grid, the transmission system operator (TSO) and the distribution system operator (DSO). The TSO operates the transmission system assets and is responsible for the power balance on the transmission system. The DSO operates the distribution grid, and, in some markets, may additionally act as a retailer. The second group of market players are those who buy and sell electricity. The generating company owns production facilities (from a single generator to a portfolio), whose generation is offered through the electricity market. The retailer buys electricity engrossed from the wholesale electricity market, to then to be sold to the end-consumer. The consumers (large and small) are those who eventually use electricity. Large consumers might be allowed to buy directly from the wholesale market. Finally, there are the market players who rule and operate the game. The regulator is responsible for the market design and its specific rules. They also monitor the market, to spot misbehavior in electricity markets (e.g., market power abuse). The market operator organizes and operates the marketplace. This may include the definition of bid products and bid forms, set up and maintenance of the trading platform, daily matching of supply and demand and offers, etc.

The transition towards decentralized energy systems based on renewable sources will invoke changes in the energy market, including in the set of market actors. As consumers are turned into prosumers, their role and responsibilities within the market change. The decentralized and intermittent nature of renewables-based energy systems also gives rise to new market actors, such as aggregators in distributed energy networks (Kerscher & Arboleya, 2022).

2.5 Local energy communities

Energy communities provide a way to organize collective energy activities, usually on the local level. They connect different energy users to facilitate the local exchange of energy, and are based on democratic participation and decision-making by its local stakeholders, making it easy for citizens to become involved in their local energy system. The EU has recognized energy communities as an important part of the energy transition, emphasizing their “substantial added value in terms of local acceptance of renewable

energy and access to additional private capital which results in local investment, more choice for consumers and greater participation by citizens in the energy transition" (European Union, 2018).

Energy communities can take a wide range of legal forms, e.g., an association, cooperative, non-profit organization or small business. Depending on the specific legal framework, energy communities may engage with a range of energy activities, including energy generation, distribution, supply, aggregation, consumption or storage, as well as different energy-related services, for instance related to charging infrastructure for electric vehicles. They can thus play a central role in the local energy market. While the EU's revised Renewable Energy Directive (2018/2001) and Internal Electricity Market Directive (2019/944) have provided a framework for renewable energy communities and citizen energy communities, respectively, to be established and integrated into the energy markets in the Member States, they have left considerable room for national legislation to determine the details of energy communities' characteristics. Consequently, specific legislation on energy communities varies from country to country within the EU and there is no broadly accepted definition or organizational structure for them (Frieden et al., 2021).

3 Goals and characteristics of the SERENE project

3.1 The SERENE project

The SERENE project 'Sustainable and Integrated Energy Systems in Local Communities,' funded via the European Union's Horizon 2020 research and innovation programme, aims to develop sustainable, integrated, cost-effective and customer-centric energy solutions for villages and small cities, and to demonstrate them in real European communities. It includes smart technological, socio-economic, institutional, and environmental solutions to enable local management of integrated energy systems and networks, utilization of a high share of locally generated renewable energy, and active consumer engagement. Innovations developed within the project will aim for eventual market introduction, to allow replicability in other energy communities.

The SERENE consortium comprises public and private organizations as well as research institutes from Denmark, the Netherlands and Poland, and works in close collaboration with various key actors in the different demonstration sites. Beyond the partnerships needed for specific interventions, the SERENE project also puts key emphasis on the active participation of consumers. This allows for the assessment of changes in consumer behavior and the social acceptability of innovations developed in SERENE.

By combining the development of new technological solutions for the local generation and use of renewable energy with the analysis of social dynamics in the demonstrators, the SERENE project provides new insights on local energy system transitions that can support future transition processes across Europe and beyond.

3.2 Demonstrator sites

Three villages in Denmark, the Netherlands and Poland serve as demonstration sites for new local energy systems. The three sites differ in geography, socio-economic conditions, institutional structures and characteristics, and available energy resources, as well as in the interventions planned within the SERENE project. This section briefly introduces each demo site, providing a baseline for more in-depth discussion of specific characteristics in Section 5.

3.2.1 Skanderborg, Denmark

The two Danish demo sites in the villages Låsby and Hylke are located within the municipality of Skanderborg in Midtjylland (Central Denmark Region). Skanderborg municipality has 62,000 inhabitants, 18,000 of whom live in its main town of Skanderborg, with a population density of around 145 people per km² (compared to 102 people per km² in Midtjylland and 137 people per km² across Denmark). Based on data from 2015, the municipality of Skanderborg has the highest average income per capita within Midtjylland, at 333,338 kr per year (ca. €44,800), compared to 293.115 kr per year in Midtjylland and 308,144 kr per year across Denmark (Region Midtjylland, 2017). The age distribution of Skanderborg's population shows an overrepresentation of families with children and an underrepresentation of young

adults between 20 and 30 years old, compared to regional and national averages (Figure 3.1). This is related to many young adults moving away from Skanderborg for their studies, for instance to neighbouring Aarhus.

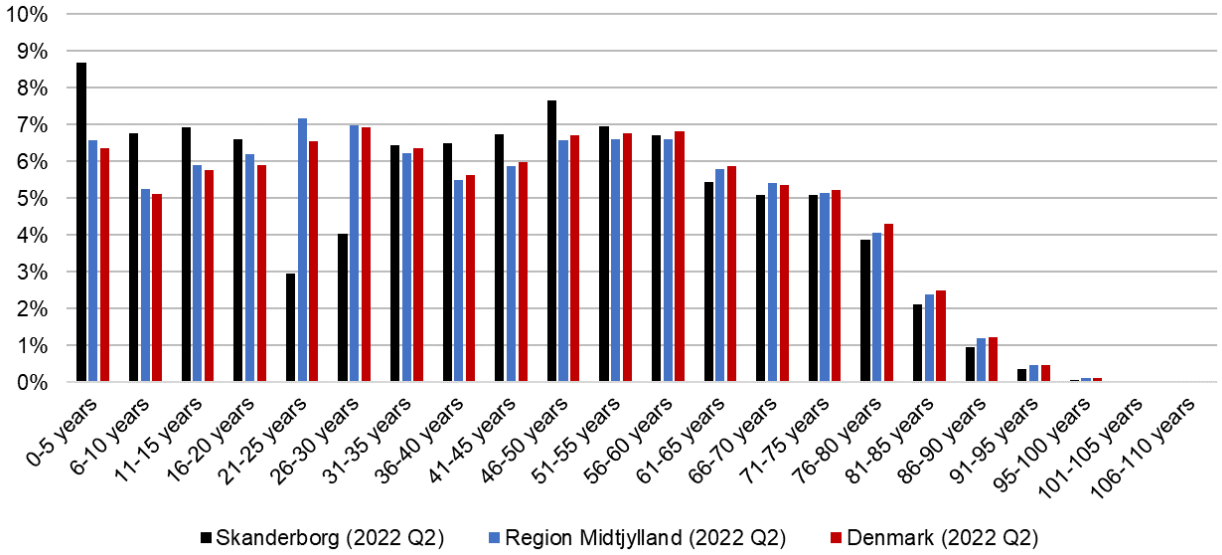

Figure 3.1. Age distribution in municipality Skanderborg, Region Midtjylland and Denmark for 2nd quarter of 2022. Data source: Danmarks Statistik (https://www.statistikbanken.dk/statbank5a/).

Across the municipality of Skanderborg, around 44% of the total energy consumption are currently covered by renewable energy sources, with the plan to increase this to 100% by 2030 in line with national ambitions. The municipality also aims for a 70% reduction in CO_2 emissions from heating, electricity, transportation and farming by 2030, compared to 1990.

In the village of Låsby (2,000 inhabitants), the SERENE interventions target a new development of residential buildings which will be connected to a centrally located heat pump that provides all units with heating. PV installations will additionally provide locally produced electricity.

In the village of Hylke (400 inhabitants), the SERENE project targets existing buildings owned by the local social housing corporation, where existing oil boilers will be replaced with a central heat pump and energy storage solutions. Again, PV systems will additionally provide electricity from RES.

3.2.2 Olst, Netherlands

The two Dutch demo sites are neighourhoods in the village Olst, part of the municipality of Olst-Wijhe in the province Overijssel. The municipality Olst-Wijhe is home to 18,000 inhabitants, 5500 of whom live in Olst, with a relatively low population density by Dutch standards of 152 people per km² (compared to 340 people per km² in Overijssel and 420 people per km² across the Netherlands). The average household income in Olst-Wijhe is in line with regional and national averages, at €31,300 per year as of 2019. However, higher resolution statistical data shows that the two districts in which the demo sites are located have a significantly higher percentage of high-income households and lower percentage of low-income

households than the rest of Olst (Centraal Bureau voor de Statistiek, 2019). Compared to regional and national averages, Olst-Wijhe has a somewhat higher population between the ages of 50 and 75 (Figure 3.2).

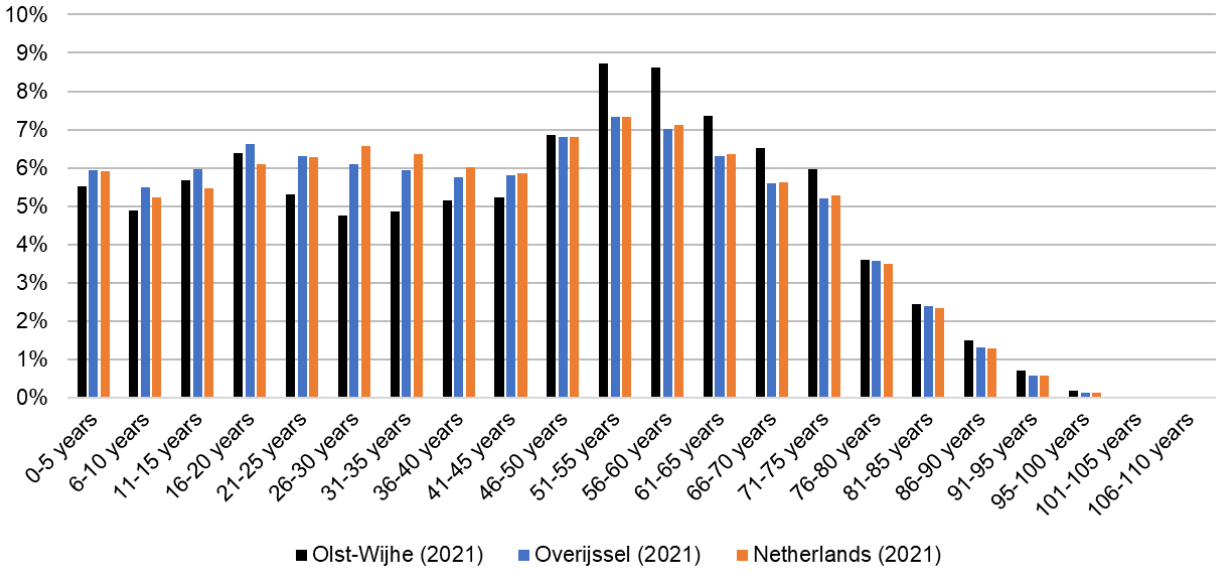

Figure 3.2. Age distribution in municipality Olst-Wijhe, province Overijssel and the Netherlands for 2021. Data source: Centraal Bureau voor de Statistiek (https://opendata.cbs.nl/statline/portal.html).

The Aardehuis neighbourhood comprises 24 houses, built in a citizen-led initiative between 2011 and 2016 according to the 'earthship concept,' a set of circular and ecological building standards (Vereniging Aardehuis, n.d.). Within the SERENE project, the Aardehuis community wants to install a neighbourhood battery and implement smart grid solutions within the neighbourhood.

The Vriendenerf neighbourhood comprises 12 houses, which were built according to nearly zero-energy building standards and finalized in 2017, also based on a citizen-led initiative. The SERENE interventions primarily focus on smart grid solutions and local energy management schemes to improve the self-sufficiency of the neighbourhood.

3.2.3 Przywidz, Poland

Przywidz is a rural municipality close to the Gdańsk-Gdynia-Sopot 'Tri-city' agglomeration in the province of Pomerania. With 6,000 inhabitants and 47 people per km², population density in Przywidz municipality is low (compared to 128 people per km² in Pomerania and 122 people per km² across Poland). The average gross wage in Gdańsk county (Pruszcz Gdansk), of which Przywidz is a part, was recorded as PLN 5014.67 per month (ca. €1080) in 2020, approximately 10% below national average. Employment in the city of Gdańsk offers significantly higher wages, and many residents of Przywidz commute to Gdańsk for their work (Główny Urząd Statystyczny, 2020). The population of Przywidz is slightly younger than the regional or national average, with a higher proportion of inhabitants between the ages of 10 and 30 (Figure 3.3).

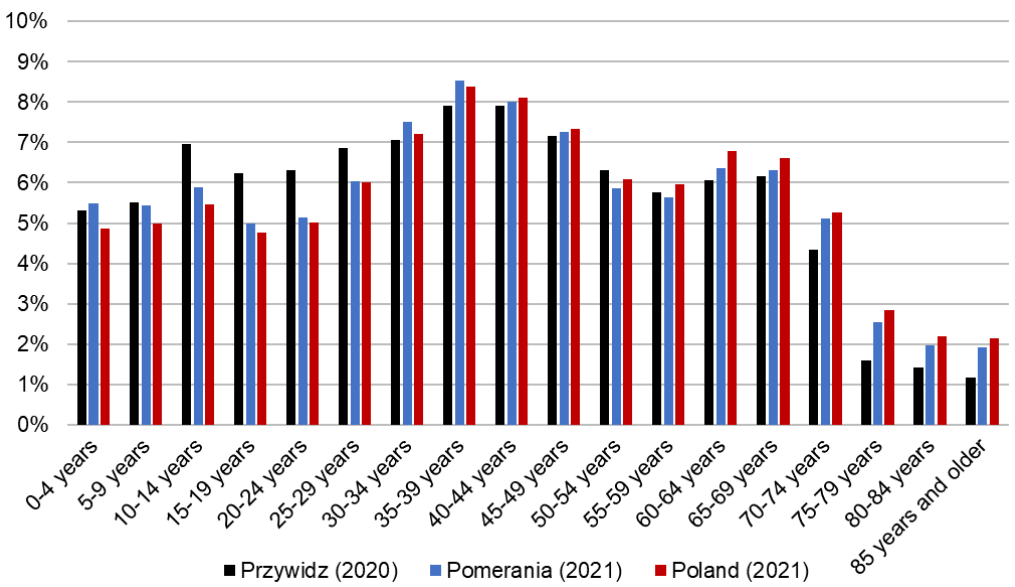

Figure 3.3. Age distribution in municipality Przywidz (for 2020), province Pomerania (for 2021) and Poland (for 2021). Data source: Główny Urząd Statystyczny (https://stat.gov.pl/).

Within Przywidz, there are three demo sites in which SERENE interventions will be implemented: a residential neighbourhood, the local school and gym, and a new wastewater treatment plant in the town. Planned interventions include the installation of heat pumps and smart energy management solutions, as well as the expansion of the local EV charging infrastructure.

3.3 Energy transition trends addressed in SERENE

The local energy system transition towards a new low-carbon citizen-based system takes place in the context of the larger energy transition and a move towards a low-carbon economy. This includes a transition from centralized fossil fuel-based energy production and centralized markets in which energy users are solely consumers towards decentralized energy production, more local energy markets and an active role of energy citizens. The digitalization of energy systems and services, new business models that explicitly include the role of citizens, and renewable energy communities as new governance models are among other key trends that will be incorporated into the new low-carbon citizen-centered energy systems.

This sub-section provides background on these characteristics and trends related to the energy transition, connects them to the local energy system transition in particular and outlines how the SERENE project accounts for them in the demonstrators.

3.3.1 Low-carbon economy

The idea of a 'low-carbon economy' refers to a sustainable economy based on low energy consumption and low CO2 emissions. While the low-carbon economy is fundamentally based on low-emissions energy

systems, it also ties in with sustainable transitions beyond the energy sector. This includes sustainable modes of production and consumption that minimize CO2 emissions throughout the product lifecycle, circular economy approaches that center the reuse or recycling of resources, and the development of carbon capture technology.

As a consequence of low-carbon transitions, the demand for energy in the form of electricity is currently increasing significantly, in particular due to the de-carbonization and electrification of the transportation and the heating and cooling sectors. Accordingly, the EU expects that electricity will almost double its share in energy consumption by 2050 compared to 2005 (European Climate Foundation [ECF], 2010). This can lead to congestion problems on local electricity grids due to insufficient transmission capacity, and costly grid reinforcement projects.

The SERENE project supports the progress made by local communities towards a low carbon economy by developing low carbon multi-carrier energy systems that enable communities to meet their energy needs from local renewable sources. These systems include local distributed generation, demand response resources and energy storage technologies in various domains like electricity, heat, water treatment and transport. SERENE also addresses issues related to the electrification of transport, heating and cooling in the demonstrator sites.

3.3.2 Decentralized energy production from intermittent renewable sources

The switch from fossil fuels to renewable energy sources is a core element of the energy transition. However, it is a gradual process, with a slowly increasing share of renewables, such as solar and wind, in the energy mix of countries and communities. While this increase of renewables in the energy mix reduces its carbon footprint, the intermittent nature of key renewable energy sources also leads to various capacity and cost problems in transmission systems and local distribution systems. It creates balancing and congestion challenges at the local as well as the global level, which need to be addressed through flexibility measures in the system, for example storage facilities and demand response from private and industrial users.

Additionally, the transition from a fossil fuel-based energy system to a renewables-based energy system goes hand in hand with the decentralization of the system. Relatively inflexible, often large-scale conventional power plants, such as coal and nuclear, are being replaced by more flexible systems with decentralized or distributed energy production from local intermittent renewable sources. This comes with challenges for both the design of physical infrastructure, e.g., the local electricity grid, and the management and regulation of the energy sector.

Depending on the characteristics and needs of each demonstrator site, the new local energy systems in SERENE involve a variety of decentralized renewable energy production facilities, as well as different storage technologies (battery energy storages, heat storages, water storage-systems) and demand response systems to enhance the flexibility of the systems.

3.3.3 Energy system flexibility

System flexibility in local distributed energy systems and the system's ability to balance fluctuations in energy production go beyond technical measures, such as storage technology, and control measures by the distribution system operator. With a growing role of energy users in the production, transport and consumption of electricity, their role with regards to balancing and ensuring system flexibility increases as well.

The modernization and implementation of smart grid solutions are central to dealing with the flexibility demands linked to the increased share of renewables. For the overall stability and security of electricity systems dominated by renewables, active distribution grids have a larger role to play in balancing the supply and demand and providing ancillary services from the local distributed generation, loads and storage units in small communities. Smart grid solutions are therefore a core feature of the local energy systems in the SERENE project.

To be visible to the system operators and interact with the electricity market to deliver such services, the smaller distributed energy resources have to be aggregated as local multi-carrier and multi-domain clusters of energy systems that can exploit economical and technical synergies. This also necessitates active load management that cost-effectively satisfies customer comforts, expectations and needs. For the demand control to be part of the electricity retail market, the SERENE project will set up guidelines for flexible pricing, consumer involvement and smart metering interface and interactive control set-ups.

Additionally, SERENE focuses on the interaction among the different energy sectors, which poses a challenge for the technical and economical operation of electricity networks. SERENE will analyze the existing market infrastructures, regulatory framework, data handling and system operations to create new insights on the complex interdependencies between systems and components with multiple options, markets, regulations and parties. These activities shall enhance the flexibility and efficient operation of the local electricity grids and energy networks, and further contribute to the larger energy system. Since current practices are inadequate to enable active grid management and utilize vastly unexplored local flexibility and storage solutions, new energy management procedures will be invented and demonstrated.

3.3.4 Multi-carrier energy system integration

In the EU Strategy for Energy System Integration (EC, 2020), the EU notes that today's energy system is built on several parallel, vertical energy value chains, which rigidly link specific energy resources with specific end-use sectors. Electricity and gas networks are planned and managed independently from each other. Market rules are also largely specific to different sectors. This model of separate silos cannot deliver a low-carbon economy. It is technically and economically inefficient, and leads to substantial losses in the form of waste heat and low energy efficiency. For the EU, energy system integration – the coordinated planning and operation of the energy system 'as a whole', across multiple energy carriers, infrastructures, and consumption sectors – is the pathway towards an effective, affordable and low-carbon economy.

In line with the EU strategy, SERENE will apply a holistic system approach to identify efficient and economical ways for the harmonized operation of heterogeneous energy carriers (electricity, heating,

transport, water etc.) and infrastructures in locally integrated 'energy islands' or integrated community energy systems.

3.3.5 Citizen-centered energy systems

The EU sees local energy communities and energy active citizens as key for the energy transition in all EU member states. Local energy communities are groups of citizens and communities that collectively organize decentralized energy actions, for instance in the domains of renewable energy, energy efficiency, and energy service provision. Benefits of stimulating the role of active citizens and local energy communities include: 1) facilitating collective and citizen-driven energy actions to pave the way for a clean energy transition; 2) increasing the public acceptance of renewable energy projects; 3) attracting private investment in the clean energy transition; 4) providing flexibility to the electricity system through demand-response and storage by supporting citizen participation; and 5) providing direct benefits to citizens by advancing energy efficiency and lowering their electricity bills (Coenen & Hoppe, 2021).

Local citizens and communities need to be involved in the changes made to the local energy system, and informed about different technical opportunities and business cases, so they can make informed decisions about their participation in different elements of the SERENE project. The role of local energy communities as a social innovation that enables certain technological innovations, like collective energy production, will further be explored in the project. Active community participation is also expected to increase consumer awareness and the social acceptance of technical innovations.

One of the arguments for a larger role of citizens in the energy transition is that they can economically benefit from it. This relates to both lower energy bills and private citizens' investments. In a distributed local energy system, profits from the production of renewable energy would not only be made by the big market actors, but also by local citizens as (collective) prosumers and active energy consumers. Beyond that, the new local energy system sparks new economic activities that create jobs in manufacturing, installation, and more. Furthermore, there are positive social impacts, such as stronger community solidarity and spirit, as many renewable energy activities take place within the local community. Distributed energy generation can also empower local communities, as they are given the ability to manage and operate decentralized energy systems themselves.

The SERENE project aims to demonstrate solutions to effectively integrate different energy system carriers and enable communities to meet their energy needs from local renewable energy sources, by focusing on attractive citizen-centered business models and local economies. It brings benefits to the local communities, such as enhancing the local economy, reducing exodus to cities, creating new employment and business opportunities, improved air-quality, community empowerment and capacity development for smart solutions, and better energy and transport infrastructure.

3.3.6 Digitalization

Digitalization is an important process going hand in hand with the energy transition. Besides new energy-related digital technologies, existing facilities can be enhanced to utilize new software, data or models, for instance to monitor and reduce CO2 emissions. System-wide digitalization is part of the EU Strategy

for Energy System Integration (EC, 2020), which sets out key actions to drive the clean energy transition. The 'Digitalising the energy sector' action plan (EC, 2021) aims to support the development of a sustainable, (cyber)secure, transparent and competitive market for digital energy services, ensuring data privacy and sovereignty, and supporting investment in digital energy infrastructure.

4 Socio-technical systems change

Local energy transition processes are socio-technical transitions. A socio-technical energy system includes both technical components (e.g., power plants, transformers, grid infrastructure, cables, electrical equipment for end-consumption) and social components (e.g., actors, legislation, economic and political frameworks) (Van de Graaf & Sovacool, 2020). In the SERENE project, we investigate the change of the existing fossil fuel-based local energy system to a low-carbon, citizen-centered local energy system. The characteristics of this new system were outlined in Section 3. In this section, we now discuss socio-technical system change to understand how we want to study local energy system change and explore the significance of viewing the energy system as a socio-technical system.

4.1 Systems approaches

The concept of 'systems' originates from the field of physical and biological sciences, and has been taken over by social sciences from there. For the energy transition, relevant social fields like planning, management and policy studies use system concepts. The systems approach assumes that breaking down a complex concept into smaller elements helps to understand its complexity. Ludwig von Bertalanffy (1968) first introduced and formalized the systems approach as a new scientific philosophy under the name of 'General System Theory'. A key element of the system approach is that systems are open and interact with their environment. We therefore need a clearly defined boundary between the system and its environment, to help us to understand the system and its interaction with the environment from within this boundary.

Before we discuss local energy system change, we need to consider that (1) understanding the elements of a system and the networks of cause and effect within the system does not mean that we know how to *improve* the system; (2) diagnosing what is wrong with the system is different from understanding what is needed for *system change*; and (3) understanding that system change is necessary does not help identifying which *action* to take. Additionally, the fossil fuel-based local energy system is not a dysfunctional system per se – the criteria for the system simply have changed to prioritize low-carbon energy systems.

Although systems approaches can be found in many scientific disciplines, there are different conceptual notions of how you can define a system. Two main schools of thought can be distinguished across disciplines: 'hard' and 'soft' systems approaches (Reynolds & Holwell, 2010). Hard systems thinkers look for concrete problems and solutions for clearly defined systems, while soft systems thinkers focus more on people and their perspectives of a system. The soft systems approach is less about concrete solutions, and more about making sense of unclearly defined problems.

The different types of interventions in the SERENE project (technical and social innovations) match with different ideas of hard and soft systems change. In the 'hard systems' approach, systems are seen as concrete or physical entities that exist in the real world. This approach assumes that the problems associated with 'hard' systems are well-defined and have a single, optimal solution. This scientific

approach to problem-solving relates to solutions that are dominated by technical factors. From a local energy system perspective, this means that the local energy system has clear boundaries and both physical and social components exist. Additionally, it assumes that the local energy system, in particular its technical parts, can be described and modeled (Reynolds & Holwell, 2010). The hard systems approach holds the assumptions that people are, in principle, rational and that systems are tangible.

However, the local energy system transition is not just about technical change, whereby social factors are seen as obstacles that we need to overcome to successfully implement technical innovations. In such a 'technical change-dominant perspective' on system transition, policies, regulation and costs are seen as conditions to change and fit to the new technical systems. Yet system change also faces social and cultural barriers. This includes, for instance, the wider public discourse around energy systems and attachment to fossil fuels (Sovacool, 2009), and social acceptability problems. Attitudes towards renewable energy are not always rational, but rather driven by emotions and psychological issues (Lenoir-Improta, Devine-Wright, Pinheiro, & Schweizer-Ries, 2017). The local energy system transition also asks for new forms of active citizenship (Devine-Wright, 2007) and cooperation between citizens, including peer-to-peer transactions.

Consequently, in SERENE, we do not only look at technical innovations, but also at social innovations, defined as *"innovative activities and services that are motivated by the goal of meeting a social need and that are predominantly diffused through organizations whose primary purposes are social*" (Mulgan, 2006, p. 146). Social innovations in SERENE are necessary to complement technological innovation in order to enable a transformation towards more sustainable local communities. However, social innovations are more than simply non-technical enhancements to the system.

The soft systems approach views systems as social constructs rather than concrete entities. In contrast to the hard system approach, it considers problems as ill-defined or not easily quantified and tries to understand people's perspectives of a system. From this perspective, a local energy system could be seen as a system to secure energy delivery to consumers, to deliver energy at affordable prices, or to lower the carbon footprint of energy-related activities.

4.2 A holistic perspective on systems

At first glance, a hard systems approach may appear more suited for a local energy system as a system with clear boundaries. However, this primarily holds for the physical and technical side of the system, but not for the complex social dynamics underlying the local energy transition. A local energy system is a combination of this physical and technical system and the complex social system around it, where the components of the system cannot easily be summed up. In SERENE, we therefore apply a holistic perspective that considers the co-evolution of different system elements. This is a common approach in contemporary studies on socio-technical transition in the energy system (Bauknecht, Andersen, & Dunne, 2020; Bettin, 2020).

From this holistic perspective, a change in one system component, no matter if technical or social, affects other components directly or indirectly. The specialist purpose of smaller system components is nonetheless important, and it is essential to understand each component to get a holistic perspective

(Boulding, 1985; Litterer, 1973; von Bertalanffy, 1968). In the energy system, this includes, for instance, how different usage patterns or market coordination mechanisms affect system processes and the suitability of various technical solutions for a given system (Rassa et al., 2019).

A further part of the holistic view is that there are emergent properties of the system, e.g., the social components, that have characteristics which are not present in any other individual component. A reverse salient refers to a component of a technological system that, due to its insufficient development, prevents the system in its entirety from achieving its development goals (Hughes, 1993). In SERENE, we do not see social components as a reverse salient part of the system. On the contrary, many social factors might be what Meadows (1999) calls 'leverage points,' i.e., places to intervene within a complex system where a "*small shift in one thing can produce big changes in everything"* (p. 1).

4.3 Transition management

How does system change come about? In the SERENE project, we consider the change of the local energy system as system transition, which we can define from the transition management literature: "*A transition can be defined as a gradual, continuous process of change where the structural character of a society (or a complex sub-system of society) transforms".* (Rotmans, Kemp, & van Asselt, 2001, p. 16). We consider the processes of innovations as the key to the transition, including both technological change (technological innovations) and social change (social innovations). We use the key concepts from transition management – the multi-level perspective (MLP) theory and strategic niche management (SNM) theory – to conceptualize how the system changes come about. These theories take an integrated perspective on sustainability transitions, and particularly account for social system elements and dynamics.

Innovation can be seen as a process in three stages: First, the stage of invention is the creation of new knowledge that leads to a new product or production process. Second, the stage of innovation is the improvement of the new product or production process for commercialization. Third, the stage of diffusion is the process whereby the product or process reaches the buyers in the market (Schumpeter, 1912). These stages are formulated as a linear process, though in practice many inventions never reach the innovation stage, and many innovations never completely diffuse. While SERENE focuses on chosen innovations in the demonstrators, it does not directly deal with questions of why inventions do not become innovations or why some innovations are adopted and others not. Nevertheless, the diffusion of innovations does play a role in the project.

Rogers (1962) states that diffusion is the process by which an innovation is communicated over time among the members of a social system. The 'diffusions of innovations' theory seeks to explain how, why, and at what rate new ideas and technology spread through cultures (Rogers, 1962). The SERENE project seeks to contribute to the diffusion of new sustainable technologies. Niches innovations as experiments that are protected by public and private measures gives the possibility to learn about these new technologies. However, using SNM takes us away from simply looking at an innovation introduced to an

existing market. The replication potential of the innovations in the SERENE project to other sectors and places is addressed in WP 7.

4.4 Multi-level perspective on transitions

At this point, it is useful to define the three basic concepts or levels within transition management system theory: regimes (meso), niches (micro) and landscapes (macro). The meso-level regime refers to the dominant practices, rules and technologies that provide stability and reinforcement to the prevailing socio-technical systems (Geels & Raven, 2006). The definition of regime is expanded from technological regimes, defined as '*a set of rules embedded in an engineering community's institutions and infrastructure which shape technological innovations,'* to a 'socio-technical regime,' including the established practices of social groups such as policy makers and financiers, not just the engineering community (Geels, 2002).

The niche is the micro-level, or the space provided for radical innovation and experimentation. In SERENE, we consider the different technical and social innovations as niches. Besides the regime at the meso-level and the niche at the micro-level, there is also the macro-level of the landscape. This refers to the overall socio-technical setting as a wider political, cultural and economic context. The landscape for the local energy regime could, for instance, be characterized by factors like energy prices, geopolitical conflicts and energy shortages, but also environmental awareness and energy- and climate-related social values, political beliefs and world views.

System change can occur at the regime level, although only incrementally. Changes also occur in the landscape, but at an even slower pace. Such landscape changes can put pressure on the regime, which provides openings for new technologies to establish themselves. In the SERENE project, the change takes place in the regime, i.e., local energy system. Niche innovations in the form of technical and social innovations need to be introduced in these local energy systems, to eventually alter the existing regime. Compared to the existing fossil fuel-based energy system, low-carbon system can lead to some disruptive and radical system changes.

The socio-technical regime determines which niches are successful in becoming part of the regime or overtaking (parts of) the regime. The idea is that the 'best' innovations are incorporated into the existing regime. This uses an evolutionary perspective where some niche innovations are selected, while others are not. The factors we discuss in this deliverable, and the obstacles we identify in deliverable 3.2, can be placed within this perspective. Radical innovations occur in niches, which act as safe environments for breakthrough developments, sheltered from the selection process that occurs at regime level.

A regime may host a range of niche innovations that challenge the existing local energy system regime. Niche-accumulation occurs gradually when processes at the regime and landscape level present 'windows of opportunity' for new innovations to exploit and become established through so-called breakthroughs. Figure 4.1 visualizes these processes from a multi-level perspective, highlighting niches, regime and landscape.

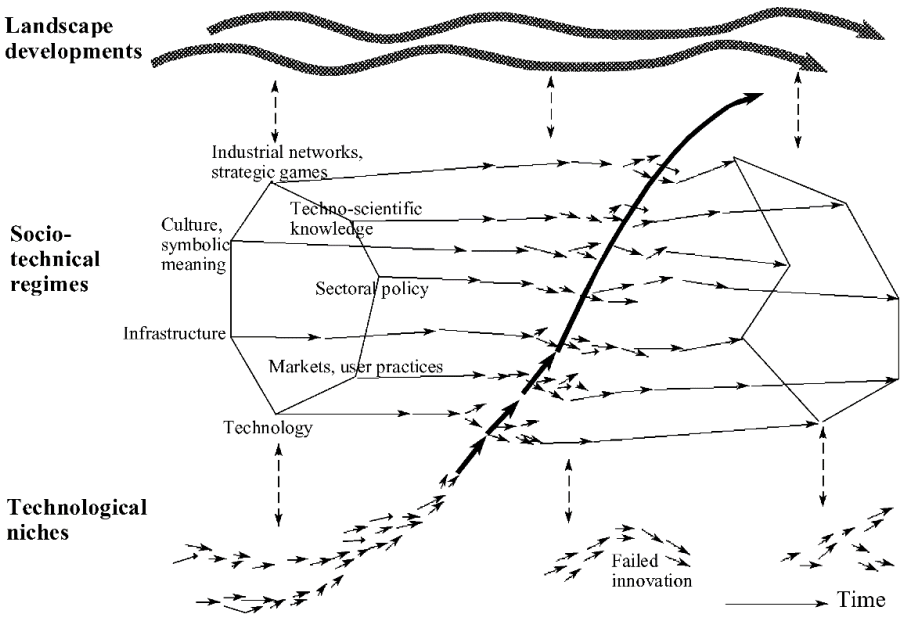

Figure 4.1. A dynamic multi-level perspective on socio-technical transition. Source: Geels (2002).

4.5 Transition phases

A transition is a non-linear regime shift from an initial state of a relatively stable system towards a period of relatively rapid change, in which the system reorganizes irreversibly into a new system (Rotmans et al., 2001; Verbong & Loorbach, 2012). The process of a transition brings this status quo out of its balance and causes it to shift towards a new state of balance. Transitions have the following main characteristics: (1) they are co-evolutionary processes that require multiple changes in socio-technical configurations; (2) they are multi-actor processes, involving a large variety of social groups; (3) they are non-linear radical shifts from one configuration to another; and (4) they are long-term processes on a macro-level (Rotmans et al., 2001).

For the SERENE project, the initial state is the existing fossil fuel-based local energy system. The status quo already includes some integration of renewable energy sources. The new state at the end is the low-carbon, citizen-centered, economical viable system the SERENE project strives for. Deliverable 3.3 will elaborate on how we plan to identify the initial state for each demonstrator.

It is important to note that transitions are not uniform, and nor is the transition process deterministic. The transition management literature recognizes that there are large differences in the scale of change and the period over which it occurs (Rotmans et al., 2001). Transitions involve a range of possible development paths, whose direction, scale and speed government policy can influence, but never entirely control. They are therefore dependent on many factors that need to coincide for specific outcomes to manifest.

In the literature, transitions are conceptualized to happen in four phases (see Figure 4.2; Rotmans et al., 2001):

- *Predevelopment:* This is the phase of dynamic equilibrium that a system is in before any transition is proposed or catalyzed.
- *Take-off:* In this phase the change starts to take root in the system because of an internal or external force being introduced. The new development starts to become a significant niche that cannot be ignored by the incumbent system.
- *Acceleration:* The systemic change starts to become visible and picks up strength due to an accumulation of changes amongst different dimensions in the system, reinforcing the transition trajectory. Both push and pull factors start to cause the development to gain ground and become more established as an alternative in the system.
- *Stabilization:* In the last phase, the intensity of change has diminished to the point where a new dynamic equilibrium is reached. At this point, the development has stabilized as part of the system, irrespective of the level it has reached. The momentum has stagnated, and the system has stabilized around the new equilibrium.

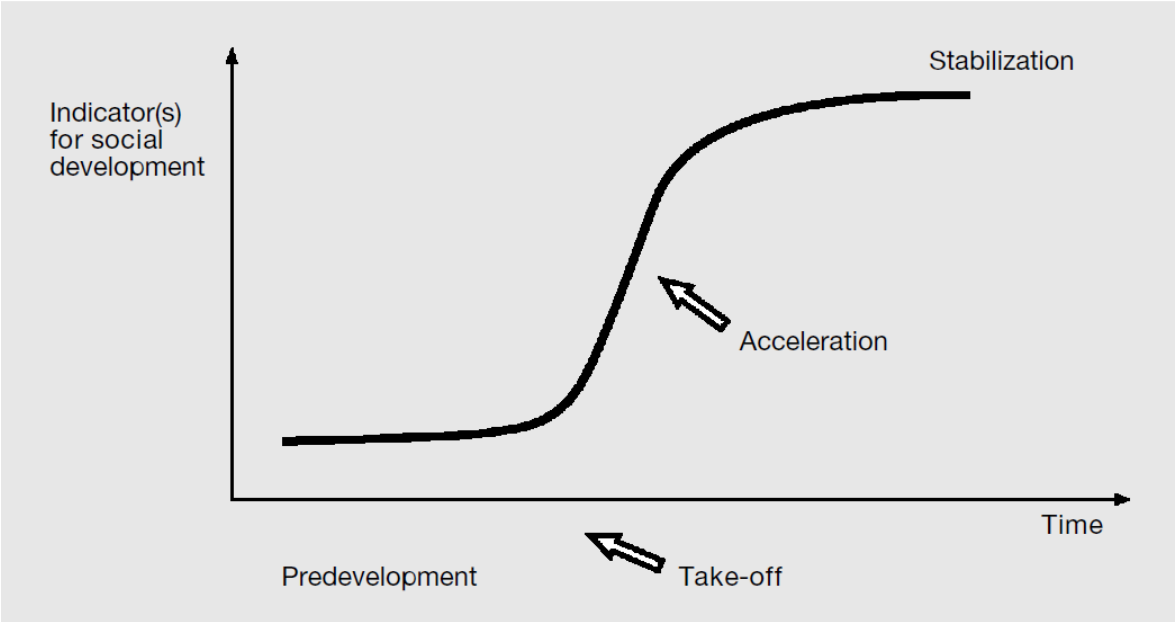

Figure 4.2. Transition phases in socio-technical transitions. Source: Rotmans et al. (2001).

In the predevelopment phase, a regime is relatively stable, but increasingly unable to adapt to systemic shocks (autonomous macro-events) and (technological) niche developments. During the take-off stage, the regime 'opens up' and 'cracks', the transition enters a reconfiguration and acceleration phase in which elements of the new and old regime are combined.

The specific socio-economic and regulatory conditions in society either enable or disable the development of technological innovation in the socio-technical system. Following the MLP framework (Geels, 2002), the SERENE innovations are niches that can develop and grow into a niche-regime with the power to overthrow and replace the existing regime. Strategic niche management (SNM) is essentially another approach to stimulate system innovation, which advises the use of societal experiments to create and further develop niches to induce system innovation. The process of niche experimentation is defined as "*creation, development and controlled break-down of test-beds (protected spaces for experiments,*

demonstration projects) for promising new technologies and concepts with the aim of learning about the desirability, to enhance the rate of diffusion of the new technology, and ultimately, to develop a new socio-technical regime" (Hoogma, Kemp, Schot, & Truffer, 2002, p. 195).

5 Factors influencing local energy system transitions

As described in the previous section, local energy system transitions are conceptualized as complex socio-technical systems consisting of both technological artefacts and societal decision-making entities. This implies that local energy system transitions are influenced by technological trends in the local energy landscape, such as increased electrification and decentralization of the energy system; but also by various societal factors, such as regulatory boundaries or urban planning decisions. This deliverable focuses on the latter societal factors and studies these from six key perspectives (Figure 5.1): 1) socio-economics, 2) regulations, 3) governance, 4) urban planning, 5) social acceptance, and 6) societal debates. For each perspective, this section first provides a set of factors through which processes related to the perspective can influence local energy systems transitions. It then assesses the related conditions in the SERENE demonstrators and identifies areas in need of attention during the implementation of SERENE activities and potential future research questions related to local energy systems transitions. More elaborate, general explorations of the factors in each social perspective can be found in the extensive literature reviews in the appendix (Section 8).

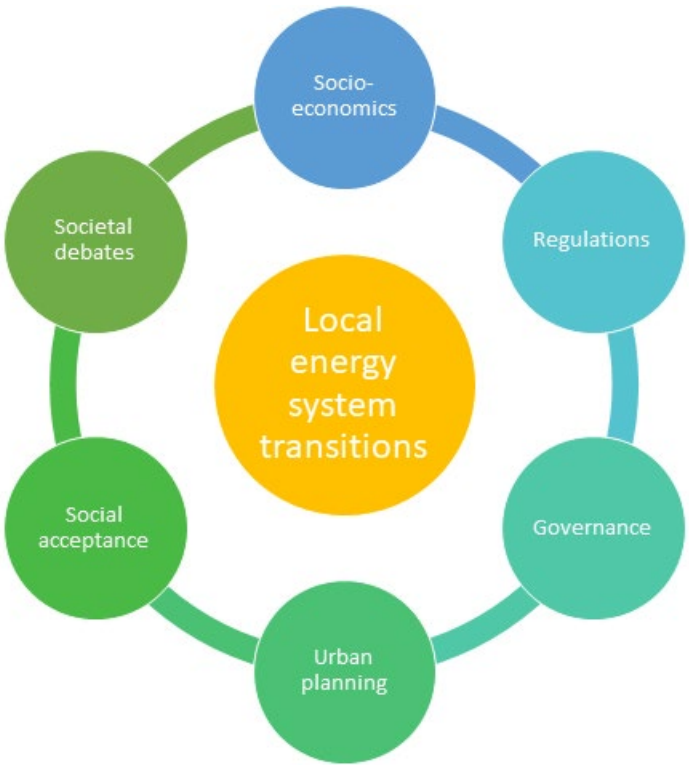

Figure 5.1. The six social science perspectives used in this report to assess social factors that affect the local energy system transition.

5.1 Socio-economics

The domain of socio-economics within the social sciences studies how economic activities and social processes are interrelated, and how this influences the economy. In the context of the local energy system transition, there are a range of socio-economic factors that influence how people use energy and interact with the energy system, both at the individual level and as part of a larger community. Socio-economic factors also tie into energy processes on a larger scale, for instance related to energy prices which react to developments and disruptions on the global energy market, with implications for the affordability on a local scale.

5.1.1 Socio-economic factors in the local energy transition

We identified three broad socio-economic factors of importance for the local energy transition. For the full literature review and argumentation on these factors, refer to Section 8.1 in the appendix.

First, the individual socio-economic circumstances of a person determine the ways in which they are able to engage with the local energy system and its transition. This includes, for instance, their household income, home ownership and the energy efficiency of their home. People with insufficient means to meet their own basic energy needs are considered 'energy poor' (EC, n.d.) and will likely require additional support to participate in the local energy transition.

Second, personal motives and ideals influence *how* people are willing to engage with the energy system and transition. While many people are primarily guided by their individual circumstances, for a part of the population, there is a willingness to pay more or make more effort for environmentally responsible energy and other additional local collective interests (Koirala et al., 2016). Local initiatives involving cooperation with neighbors or like-minded people within a region are an incentive in this regard (Knapp et al., 2020; Danne et al., 2021; Karasmanaki, 2021; Mamica, 2021).

Third, interactions between technology and market conditions determine which energy-related behaviors are feasible and affordable to local residents. Technological development can, for example, provide energy consumers with new tools to monitor their use and stimulate more efficient consumption. Advancements in the decentralized production of electricity further cause changes to the electricity market conditions.

5.1.2 Socio-economic conditions in the demonstrators and implications for SERENE

Similarities and differences in the socio-economic characteristics of the three demonstrator sites play an important role for the selection of suitable technological and social interventions and their implementation throughout the SERENE project. This includes issues on the individual level as well as the larger socio-economic context of each site. Details on both will be captured through a survey in the demonstrator communities, to assess local residents' ability and willingness to actively participate and interact with SERENE. In addition, we discuss several specific socio-economic issues that warrant close attention throughout the project in the demonstrator sites below.

Incentives and investments

The desire to have cheap and reliable energy supply is an important driver for the transition towards more cost-effective energy technologies. In this context, the current spike in energy prices provides a powerful incentive to re-think fossil fuel-dependent, particularly gas-dependent, energy systems and transition towards other energy sources, both on an individual or household level and as broader communities. Beyond that, governments commonly provide economic incentives in the form of different subsidies or tax exemptions for RES to different energy users, for instance to stimulate local renewable energy production by households or companies. Household surveys across European countries in 2021 showed that households in Denmark made use of government subsidies for sustainability home improvements most often, with 33% of households reporting they had used subsidies before, indicating a high availability of relevant subsidies and good access to information about them. The Netherlands and Poland ranked much lower, with 20% and 14% of households, respectively (USP Marketing Consultancy, 2021a; Figure 5.2). Such subsidies can also be a solution to split-incentive issues with rental properties, i.e., situations in which the building owner needs to provide the investment to implement energy-saving measures, but the tenant benefits from the lower energy bills.

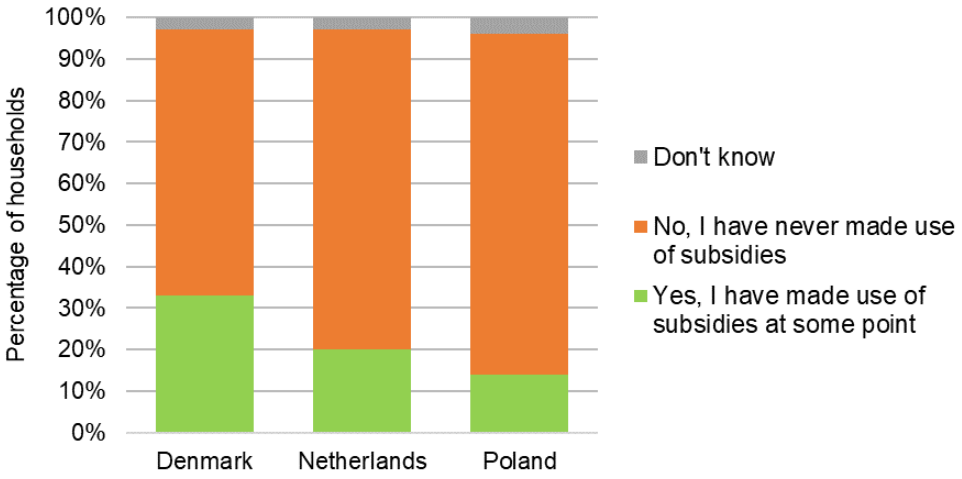

Figure 5.2. Percentage of households that have made use of government subsidies for sustainability home improvements, as surveyed in 2021. Data source: USP Marketing Consultancy (2021b).

While all three countries included in SERENE have government subsidies to support the transition towards RES, the situation in Poland warrants attention at this point. New Polish legislation has very recently caused changes to RES financing, switching from a net-metering model to a net-billing model, which significantly reduces the profitability of decentralized renewable energy production (Trela & Dubel, 2021). Polish key actors reported on the severe negative impact on economic incentives for households that are connected to this new legislation. The switch from net-metering to net-billing is a dynamic transition process which started on 1 May 2022, with new systems installed after 1 May being part of the new system, and old systems being transferred step by step. This led to a boom in PV installations on private houses in the weeks before the deadline, with key actors citing several thousand new PV installations per day. In May, with the new system in place, the demand plummeted, and residents are currently waiting

to see how the energy market will adjust to the new regulation and whether the switch to PV will still be profitable on a household level.

Along with the access to potential subsidies, the broader socio-economic conditions, e.g., the disposable income available to households, play an important role in determining who can afford to transition to RES technologies and who cannot. Section 3.2 provided some basic insights on the economic strength of the demonstrators, showing that Skanderborg and the parts of Olst in which the demo sites are located both have a relatively high household income compared to other parts of their regions and countries. Przywidz on the other hand has relatively low household incomes. Polish key actors also reported that local residents have started to approach the municipality for help with financing new RES technology.

Next to economic incentives, the transition to local renewable energy systems may be motivated by the current (lack of) security of supply or the wish for energy autonomy. While a low reliability or quality of the current energy supply has not been mentioned in the context of any demonstrator, the two community-led projects in the Dutch demo sites are motivated by the desire to be energy self-sufficient and as independent as possible from the larger grid.

Connected to the different incentives and motivations for energy transitions is the willingness to pay extra for energy from RES. In cases where the transition is primarily financially motivated, like in Denmark and Poland, the willingness to pay extra for green energy is relatively small, as there is little incentive to switch to green energy if it costs more than the current energy supply. Where the transition is primarily ecologically motivated, like in the Dutch demonstrators, there is some willingness to pay higher energy prices if it guarantees local production from RES. Dutch key actors indeed indicated that most residents would probably be willing to pay extra, but specifics depend on the individual circumstances and disposable income of each resident.

Energy poverty

While there is no universally accepted definition of energy poverty, it is broadly understood as “the inability of a person or family to keep their dwelling adequately powered and warm during the winter or cool during the summer” (Filippidou et al., 2019, p. 1199). In the European context, a household having arrears on energy utility bills and a high percentage of household income being spent on energy services are often considered as a specific indicators of energy poverty (Palma & Gouveia, 2022). It should also be noted that energy poverty does not affect all population groups equally, with the elderly and women at a higher risk of energy poverty than other groups (Feenstra, 2021).

Energy poverty is more wide-spread in Poland than in the Netherlands and Denmark, in line with the overall trend of higher rates of energy poverty among countries in Eastern and Central Europe than among countries in Western Europe (Filippidou et al., 2019; Bouzarovski & Tirado Herrero, 2017). However, recent data indicates a slow decrease in energy poverty in Poland over the past decade (Figure 5.3). It should be noted that this data only covers the period until 2018 and therefore does not include the

significant increase in energy prices across Europe in 2022, which is leading to a renewed increase energy poverty rates (Jack, 2022).

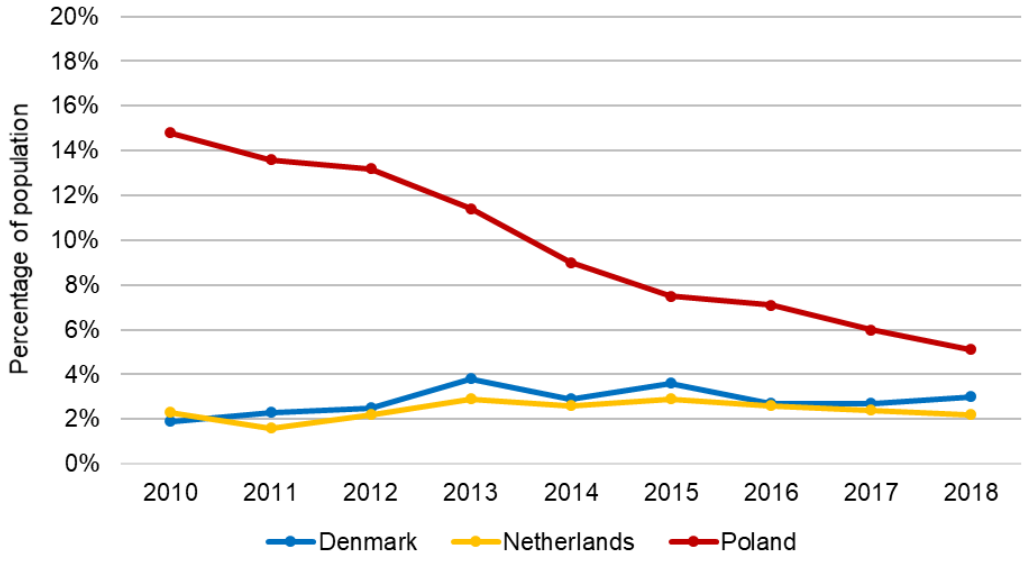

Figure 5.3. Percentage of population that is unable to keep their home adequately warm (self-reported) in Denmark, the Netherlands and Poland. Data source: Energy Poverty Advisory Hub (https://energy-poverty.ec.europa.eu/energy-poverty-observatory/indicators_en).

Little is currently known about the specific energy poverty conditions in the demonstrators. Throughout the implementation of the SERENE project, it will therefore be necessary to ascertain potential vulnerabilities among households, and ensure that interventions reduce causes of energy poverty and do not disadvantage groups that are already at risk, such as low-income households, single parents and elderly residents.

Paradigm shifts

Changes in the socio-economic conditions, technological advancements and community engagement on energy issues can lead to energy paradigm shifts within communities, for instance linked to new possibilities to locally generate energy, increased attention to sustainability issues or increased desire for local production or energy self-sufficiency. These processes are closely linked to social acceptance and societal debate dynamics, which will be further elaborated in Section 5.5 and 5.6, respectively. It is noteworthy that the Dutch demonstrators have already been on a journey towards renewable local energy systems for the past years, which has included reflections on original paradigms and motivations, as well as a careful balancing of pragmatism and idealism in how sustainability issues and the local energy transition are approached.

Throughout the SERENE project, it will be interesting to observe whether specific technical or social interventions can lead to paradigm shifts in the demonstrator communities. The current spike in energy prices additionally provides opportunities to engage a broader range of residents in energy discussions and draw attention to the advantages of local renewable energy generation.

5.2 Regulations

The energy systems upon which our current industrial society is built have traditionally been centralized, often government-controlled, centrally owned and managed entities. The regulatory framework[1] for energy was designed for this situation. With the liberalization and privatization of energy markets, new actors – privately owned and controlled energy providers – appeared. This led to new market rules and regulatory changes, which, coupled with technological developments, have created opportunities for citizen participation in the energy market. Concerns about climate change have also motivated citizens to take an active role with respect to energy production and consumption.

New or adapted regulatory frameworks are needed for a decarbonization of the local energy system. While some of these new frameworks already exist, many are still based on older or existing fossil fuel-based policies. Local energy systems based on these existing or older regulations are not always able to facilitate or encourage the required low-carbon system changes.

5.2.1 Regulatory factors in the local energy transition

We identified four regulatory factors of importance for the local energy transition. For the full literature review and argumentation on these factors, refer to Section 8.2 in the appendix.

First, the fit between the existing regulations for local energy systems and the regulations that are required to facilitate the local system transition needs to be assessed. As mentioned above, existing regulations often date back to centralized energy systems under government control and do not match the characteristics or needs of a decentralized, low-carbon energy system. This mismatch can be a hindrance to the necessary system changes that ask for new ways to generate, distribute and consume energy.

Second, the flexibility of existing laws and regulations determines whether it is practically possible to make changes in reaction to the needs of new energy systems. A lack of flexibility can, for instance, be related to overly time-consuming procedures to change a regulation, or to a lack of information about current regulation (Williams 2010).

Third, laws and regulations need to be able to keep up with the fast development pace of technical and social innovations. If laws and regulations lag behind technological developments, they inhibit the innovation needed for sustainability, and vice versa. This 'regulatory disconnect' between regulation and innovation can occur "when innovation in the market develops in a faster tempo or differently than envisaged compared to respective regulation" (Butenko, 2016, p. 702) and may, in certain cases, lead to a regulatory failure.

[1] When talking about 'regulations' in this section, we mean laws and regulations, including legal permits, planning regulations, energy standards, legally binding covenants, purchase agreements, etc.

Fourth, the regulation of energy markets and market actors plays a particularly central role for local energy transitions. Markets are never entirely free, regulations shape the playing field. These market regulations can form an obstacle, for instance due to limiting conditions under which new actors, like an energy community, can operate in the energy market.

5.2.2 Regulatory conditions in the demonstrators and implications for SERENE

In the following section, we discuss the current status of the latest EU energy directives in the three demonstrator countries, as well as specific regulatory issues in the demo sites. Note that in the interest of limiting the scope and length of this report, we do not provide a full overview of the energy regulatory landscape in the three countries, but only refer to regulations as they affect the demonstrators. We also provide guidance on potential regulatory issues related to individual interventions that may arise throughout the SERENE project implementation.

Transposition of EU energy directives

The EU's revised Renewable Energy Directive (2018/2001) and Internal Electricity Market Directive (2019/944) have provided a framework for renewable energy communities and citizen energy communities, respectively, as important elements of local energy system transitions across the EU member states. However, they were scant on details on these new energy communities' characteristics, leaving considerable room for national legislation to determine these details. As a consequence, the directives' transposition into national legislation varies from member state to member state. Additionally, although the deadline for transposition of both Directives has already passed, many member states are still in the process of drafting and introducing new legislation, including the Netherlands and Poland. REScoop.eu, the European Federation of Citizen Energy Cooperatives, is monitoring the transposition progress in the member states. Figure 5.4 provides an overview of the REScoop.eu assessment of the transposition progress and the specific legislative texts in the three demonstrator countries, with Denmark being assessed as an example of 'good practice' in the transposition, while the Netherlands and Poland score less well. It is noteworthy that all three countries are showing severe deficiencies with regards to citizen participation.

Criteria	Denmark	Netherlands	Poland
Are the criteria of the EU definitions reflected in the national legislation?			
What is the level of detail in the elaboration of principles contained in the EU criteria?			
Is the purpose of RECs and CECs clearly defined?			
Are ICA cooperative governance principles reflected in the national legislation?			
Which legal entities are allowed to be an REC/CEC?			
Is citizen participation ensured?			
Is there a designated authority to oversee RECs/CECs?			
Overall assessment			

Best practice
Good practice
Average progress
Substantial deficiencies
Bad transposition
Assessment by REScoop.eu

Figure 5.4. REScoop.eu assessment of the transposition of European Union's revised Renewable Energy Directive (2018/2001) and Electricity Market Directive (2019/944) in Denmark, the Netherlands and Poland as of end June 2022. Based on data and assessment system by REScoop.eu (https://www.rescoop.eu/policy). Abbreviations: EU – European Union, REC – Renewable Energy Community, CEC – Citizen Energy Community, ICA – International Cooperative Alliance.

Danish energy regulations relevant to the demonstrators

As outlined above, Denmark is considered a frontrunner in the implementation of the new EU energy directives. The new legislation related to these directives and other recent advances on the regulation of the energy sector has provided new opportunities for local, renewable energy systems. For instance, a key limitation for the introduction of renewables and energy access between prosumers used to be the 'behind the meter' issue: prosumers could only use local energy within their own system, i.e., behind the energy meter that connects their system to the grid and other energy users, but not exchange it with other energy users on the other side of the meter. This means that a household were able to produce and use their own energy, e.g., from a PV system or a heat pump, but any surplus had to be sold to the grid. Selling or exchanging energy with neighbours was not possible under the previous regulations. The new legislation on energy communities in Denmark provides the possibility to sell energy to neighbours to some degree, and it will be important to explore the specific implications and opportunities of the new regulations for the SERENE demonstrator. The 'behind the meter' issue is particularly relevant for the demo site in Hylke, where two buildings are supposed to be connected to a shared heat pump. In order

to be considered as behind the same meter and allow the supply of heat to all units in both buildings, the two plots would need to be turned into one parcel.

As both Hylke and Låsby aim to provide energy to the local tenants via communal heat pumps, they will need to find a solution to the right of all EU citizens to choose their own energy supplier. The current plan includes having a clause in the rental contract of prospective tenants through which they are explicitly choosing to receive energy via the communal system for the duration of their rental period. However, it still needs to be determined whether this solution is actually viable and meets the requirements of the regulatory system. There also needs to be clarity about whether building owners who provide their tenants with energy would be seen as an energy supplier and be subject to all associated regulations. For instance, suppliers of district heating in Denmark are not allowed to make a profit with the energy supply, even if they are private companies.

Dutch energy regulations relevant to the demonstrators

The Dutch energy law is still in transition as the EU directives transposition process is ongoing, with the Dutch national government currently working on a bill for the new Energy Act. This bill aims to replace the current Gas Act and Electricity Act 1998, to implement new European regulations and to give substance to agreements from the Dutch 2019 Climate Agreement. In mid-November 2021, following consultations earlier in the year, a revised version of the legislative proposal and the explanatory memorandum were sent to the relevant supervisory authorities for the formal test on feasibility and enforceability. The current net-metering scheme will continue to apply unchanged until 2023, after which it will slowly be phased out until 2031. Beyond this, the specifics of the new legislation are not clear yet, and their implications for project implementation in the demonstrators will have to be studied as new regulations are being firmed up and introduced, e.g., regarding which legal entity is most suitable to form an energy community, and how to locally store energy without legally becoming an energy supplier. In the meantime, some creative approaches to energy communities exist, such as using the national zip code regulation (postcoderoosregeling) as a starting point (De Boer at al., 2018).

The regulatory conditions in Aardehuis are different from other places in the Netherlands, as the community received several exemptions from current regulations, including a number of exemptions related to building regulations and drinking water and sanitation standards, which were important when the neighbourhood was first designed and built, and an exemption from the current energy law, which is valid until 2026. This makes Aardehuis a 'regulatory sandbox' and allows them to experiment with new local energy systems, for instance by exchanging electricity among households via the grid by building their own microgrid within the Aardehuis community. Neither are allowed under the current energy regulations. Once the exemption expires after 2026, Aardehuis will be required to meet all national regulations again, however, it is expected that the regulations will have adapted to make the Aardehuis practices legal (see also Lammers & Diestelmeier, 2017). It is noteworthy that according to local key actors, the exemption from the energy law has not actually been used so far and all energy system components in Aardehuis are currently in accordance with the applicable law, but this will most likely change as the SERENE project proceeds with its local interventions within the community.

Like in Denmark, the Dutch demonstrators need to address the EU right for citizens to choose their energy supplier. However, considering the Dutch demonstrators are community-led initiatives with the buy-in of all local residents, they face fewer problems with this regulation as all residents have actively chosen to collaborate and establish their own energy supply.

Polish energy regulations relevant to the demonstrators

The Polish energy regulation landscape is currently undergoing significant changes, with new legislation introduced very recently and the transposition of EU directives still ongoing. This has resulted in a number of inconsistencies within and between new energy regulations, and many uncertainties still remain. Regarding the implementation of SERENE, the two key issues are: 1) The dynamic transition from net metering to net billing, which was already mentioned in Section 5.1.2. Due to this transition, there are currently RES installations in Przywidz that fall under the new rule and installations that still fall under the old rule, with no clear guidelines on when they will be transferred. 2) There are new regulations on energy storage that were introduced in March 2022, which change how energy storage is accounted for in the calculation of the power capacity of a specific meter. Under the new rules, storage capacity will be added to the peak production capacity, resulting in a much higher total capacity than before. Other uncertainties with the new regulations in the demonstrator relate to the status of mobile battery systems and vehicle-to-grid EV charging stations.

The collaboration with the grid operator Energa-Operator, which is one of the SERENE partners, gives the municipality Przywidz more flexibility with regards to energy regulations, particularly for energy storage facilities. Infrastructure that is part of the operator's grid is subject to different, less strict regulations than other infrastructure. Energa-Operator therefore supports the municipality and SERENE project implementation by considering certain installations as part of their grid, rather than as installations by consumers, providing a kind of 'regulatory sandbox' for the Polish demonstrator.

In 2016, the Polish Renewable Energy Sources Act introduced the concept of 'energy clusters' as business-to-business (B2B) platforms for local action on RES. While Polish key actors reported that most of those energy clusters have since become inactive, they still exist and are registered with the government. The Zielona Brama cluster, whose coverage area includes Przywidz, could be a suitable venue to revive local B2B relations or a starting point to form a new energy community once the government has passed relevant legislation.

As part of the new energy regulations in Poland, citizens are now required to declare their domestic heat source to the municipality in order to build a central database. In Przywidz, this process has been rather slow so far, as most residents submitted their information on paper rather than using the available online tool. However, once information for the whole municipality is available, this data could provide interesting insights to SERENE and other projects working towards local energy system transitions.

Regulatory issues throughout the SERENE implementation

There is a range of regulatory issues that might arise throughout the implementation of the SERENE project and the specific interventions in different demonstrators, depending on characteristics of the

interventions. We provide a brief summary below. Additional information on pertinent regulatory issues related to renewable energy technologies can also be found in the BRIDGE report 'Recommendations on Selected Regulatory Issues from experience and knowledge,' which addresses issues related to storage ownership and procurement of storage services, storage valorization, safety and environment, new market design options, and specific regulatory aspects for island cases (BRIDGE, 2019).

Related to the regulatory conditions in the demonstrators, potential future issues or questions include the influence of regulations on the position of different actors, e.g., the role and abilities of the municipality in driving local energy system transitions, the possibilities for municipal investments or participation in local initiatives of varying legal status. In the Dutch and Polish demonstrators, the role of the 'regulatory sandbox' conditions should be reflected upon, including the lessons learned from the exemption and whether intended intervention results can still be achieved once the exemptions are removed.

A wide range of regulatory issues can arise from different technological and social interventions. However, a very common concern with any smart technology or sharing of energy and related data is privacy. There have been various publications on privacy and smart energy technology over the past years (see for instance European Data Protection Supervisor, 2012), and implementation partners should ensure that site- and technology-specific regulatory requirements are met and privacy concerns of local users addressed. Other potential issues related to specific interventions include safety regulations for PV installations, noise regulations for heat pumps in public or private spaces, rental contracts and other legislation related to the relationship between building owners and tenants, the legal status of actors involved in energy sharing systems, and legal concerns of technology innovators, e.g., in relation to liability or taxes.

Lastly, as new actors enter the energy market as prosumers or energy communities, they will have to abide by energy market regulations and fulfil certain obligations, depending on the country and their type of market involvement. This could, for example, include national and European competition laws. In addition, market regulations could influence whether local energy users are interested in taking a more active role in their energy system, for instance related to the compensation that prosumers are allowed to receive from the grid.

5.3 Governance

Energy system transitions at any level (from local to international) are often studied as technical systems of solar panels, wind turbines and storage facilities, or as economic business models of investments and revenues. However, this does not explain how energy system transitions come about, as they are also related to power, agency, institutions, legal frameworks, organizations, policies and political ideas, beliefs and motivations (Moss, Beckers, & Naumann, 2015; Young & Brans, 2017). These aspects can be combined under the heading of governance, which we define as *any and all processes, actors and institutions involved in steering policies and behavior, and making and enforcing rules, to solve a collective problem and/or ensure the provision of public goods* (adapted from Sovacool & Florini, 2012).

For local energy transitions as envisioned in the SERENE project, we particularly focus on polycentric governance, characterized by multiple centers of decision-making at different scales, which each have some degree of autonomy and independent authority to make and enforce rules (McGinnis, 1999; Ostrom 2010a, 2010b; Ostrom et al., 1961). This matches the characteristics of energy governance systems, where processes, actors and institutions exist at national, European and international levels, while simultaneously the authority of local decision-making on energy is increasing (Dobravec et al., 2021; Emelianoff, 2014; Gancheva, O'Brien, Crook, & Monteiro, 2018). Additionally, citizens, energy companies and other private entities increasingly fulfill governance functions as well, for instance in the context of local energy communities and urban energy initiatives (see Creamer et al., 2018; Horstink et al., 2020).

5.3.1 Governance factors in the local energy transition

We identified eight governance factors of importance for the local energy transition. For the full literature review and argumentation on these factors, refer to Section 8.3 in the appendix.

First, the extent to which diverse overlapping institutions and actors at multiple levels, each with some degree of autonomy, make and enforce rules affects energy governance across levels. It is important to recall that the decision-making centers are not restricted to formal governmental bodies, but can include private and community-led organizations, even if they have not formally been assigned decision-making roles. Their contribution to the governance system can range from formal rule-making over informal standard-setting to providing informational and financial support (McGinnis & Ostrom, 2011).

Second, processes of self-organization among actors and institutions shape different patterns of ordered relationships between them. These self-organization processes are a key feature of polycentric governance systems and can lead to new relationships between actors based on cooperation, competition or conflict between them or through the emergence of new actors or institutions (Carlisle & Gruby, 2019; Ostrom et al., 1961). Keeping track of such developments is crucial to understanding the continued (re)development of local energy governance systems.

Third, the presence of overarching formal and informal rules and norms ensures that objectives align across the governance system and that conflict resolution mechanisms are in place. Such rules and norms thus create the boundaries for governance activities and self-organization processes that will take place

throughout the local energy transition process (Aligica & Tarko, 2012; Carlisle & Gruby, 2019; Jordan et al., 2018).

Fourth, accountability mechanisms are needed to ensure actors and institutions involved with decision-making on various levels can be held accountable and to certain standards. Traditional mechanisms for accountability, such as electoral processes or public hearings (Skelcher, 2004), are not sufficient in polycentric governance systems where the authority to make, enforce and influence rules is dispersed among both public and private institutions and actors (Carlisle & Gruby, 2019). Unconventional accountability mechanisms might therefore be needed in polycentric energy governance systems.

Fifth, the governance system needs to acknowledge local action as crucial part of the energy transition. This is related to the principle of subsidiarity, i.e., that problems are best dealt with at the level most closely related to the problem (Dorsch & Flachsland, 2017), and the realization that while action is required on many different levels, the local level has an important role to play in addressing global environmental challenges (Ostrom, 2009).

Sixth, site-specific conditions and the characteristics of different actors determine the way in which they get involved in the governance system, and need to be considered when drafting policies for a site. It is necessary to recognize and understand the heterogeneous preferences of institutions and actors and their equally heterogeneous competencies and constraints to take certain actions, as well as the interactions between these characteristics. Accounting for these conditions can avoid inefficiencies of uniform regulations applied at broader levels (Dorsch & Flachsland, 2017).

Seventh, emphasizing experimentation and learning at different levels of governance can foster innovation processes that spill over into the overall governance system. Such learning processes can improve governance structures and reduce the costs of governance over time (Dorsch & Flachsland, 2017).

Eighth, the presence of trust in the governance system is important for effective cooperation between different institutions and actors. In polycentric governance systems, mechanisms to build trust include face-to-face communication, monitoring and graduated sanctioning (Dorsch & Flachsland, 2017; Ostrom, 2009). The implementation of such mechanisms will enhance cooperation across scales and levels to support the local energy transition.

5.3.2 Governance conditions in the demonstrators and implications for SERENE

The governance systems in which local energy system transitions occur can be seen as polycentric. Central to this concept is the fact that diverse institutions and actors are involved at multiple levels. Therefore, we start our assessment of the governance conditions by mapping the actors and institutions that are part of the polycentric governance systems which surround the three demonstrators. This mapping includes actors and institutions that were brought up by key actors or in project documents, and identifies their roles both within the local energy transition and SERENE project. We also summarize insights on the interactions between different actors and institutions, as well as the level of self-governance within the

demo sites. It should be noted that this is a preliminary mapping, and additional actors or institutions may be identified or become involved throughout the SERENE project implementation.

As a general point, it is noteworthy that when asked to sketch out the governance system in which their local energy system transitions occur, key actors from all three countries predominantly focused on institutions and actors at the local level, mentioning the role of municipalities, developers, grid operators, and so on. However, in the broader discussions on other issues related to the local energy system transitions and the SERENE project, it also became clear that these institutions and actors at the local level interact with those at the national, European or even international level. In order to adequately map the polycentric governance systems in each demonstrator, these institutions and actors on higher levels, and their role in the local energy transition, need to be included as well. The most prominent cases are the European Union, which influences local transition processes by setting EU-wide policies and legislation and is directly involved in SERENE as the project's funder, and the national governments, which play a key role by transposing EU directives into domestic legislation and may provide support schemes for local sustainability initiatives.

Denmark: Actors and institutions

In the Danish demonstrator, the key actors for the local implementation of the SERENE project are the Municipality Skanderborg, which is part of the SERENE project team, and the building developers/owners in Låsby and Hylke (Table 5.1). While several other actors, including contractors and consultants, are involved with the initial set-up of the new renewable energy systems in the respective buildings, current (Hylke) or future (Låsby) tenants of the buildings are not part of the process. Once the new heating systems are installed, the respective building owner will then enter a business relationship with the tenants, selling energy to them as needed. This means that the tenants will only act as consumers, not as producers or prosumers.

Outside of the immediate implementation of SERENE interventions, the municipality also plays an important role in the larger energy system transition. In reaction to the recent increase of energy prices, the Danish state announced that all municipalities would survey and provide information on which areas will be able to receive new district heating systems and which ones will not. Although announced by the national government, this is a decentralized process led by municipalities, with little to no national-level coordination or involvement by national-level authorities. Municipalities have also been networking to exchange experiences on local energy transitions. For instance, the Låsby village union representative in the Municipality Skanderborg is part of a group of villages that focuses on sustainable energy.

Energy projects in Skanderborg are somewhat complicated by the fact that there are two distribution system operators active within the municipality's area, whereby Låsby falls within the mandate of one DSO, while Hylke is located in the other. However, according to local key actors, the two DSOs appear to be operating in similar ways, limiting the additional work for projects that involve both.

Given the dominant role of the municipality in both the SERENE project and the local energy system transition in general, there is currently little opportunity for self-governance or self-organization by the community itself. As energy transition processes are mainly approaches as business projects with actors

Table 5.1. Preliminary mapping of the actors and institutions that comprise the polycentric governance systems around the Danish demonstrator.

Institutions and actors	Role in the local energy transition	Position in the SERENE project
European Union	Setting European objectives, rules and legislation	Project funder, via Horizon2020 programme
National government	Transposition of European legislation and designing support schemes	None
Municipality Skanderborg	Coordination of new district heating projects	Key implementation partner, SERENE project partner
EnergiTjesten	Local energy consultant	Hired by project partners
Bjerregaard Consulting	Local energy consultant	SERENE project partner
NeoGrid	Contractor for installation of smart technology	SERENE project partner
Building developer (Låsby)	Future building owner and landlord to future tenants, will be responsible for maintaining new heat pump system	Key implementation partner, external to SERENE team
Tenants (Låsby)	Energy (heat) consumers	None
Skanderborg Andelsbolig Forening (Hylke)	Building owner and landlord to tenants, will be responsible for maintaining new heat pump system	Key implementation partner, external to SERENE team
Tenants (Hylke)	Energy (heat) consumers	None
Aura Energi	Energy supplier	SERENE project partner
DSO Låsby	Distribution system operator	In conversations with project partners
DSO Hylke	Distribution system operator	Planned to be in conversations with project partners soon
Aalborg University	Research institution	SERENE project partner

from the private sector, local residents remain in the role of customers rather than being able to emerge as active energy citizens and organize themselves.

Netherlands: Actors and institutions

In the Dutch demonstrators, the two community organizations Vereniging Aardehuis Oost-Nederland and Vereniging van Eigenaren Vriendenerf Olst, along with the residents of their communities, are the main drivers of local transition towards a renewable and sustainable energy system. Consequentially, they are also the key implementation partners for the SERENE project (Table 5.2). For the most part, the two communities directly work with contractors and knowledge institutions to implement their projects, with very limited involvement of the municipality or other public sector institutions.

Key actors involved with Aardehuis provided in-depth insights on the interactions with other actors and institutions, whereby the development of a network for public outreach and the replication of ecological building projects is seen as the main objective and added value of these interactions. Aardehuis is part of the Global Ecovillage Network, which allows them to exchange experiences with ecological community initiatives around the world. They also have a close relationship with the Olst-Wijhe energy cooperative 'Goed Veur Mekare,' with an estimated half of Aardehuis residents being a member of the cooperative. When first building the Aardehuis neighbourhood in the 2010s, the community also established connections with different kinds of eco-building contractors and architects that can be involved in future replication efforts elsewhere. The involvement of these actors also increased the professionality of the Aardehuis project and ensured that Aardehuis met national construction regulations. At the same time, key actors reflected on the significant time and money required to involve and coordinate all of these actors and institutions in their activities.

As community-led initiatives, Aardehuis and Vriedenerf have a high degree of self-governance and self-organization. They play a dominant role in the local energy system transition in their communities, and have their own organization and principles which they work with. While they remain dependent on the municipality, for example when it relates to space and land issues, and on the national government, for example for support schemes and regulatory exemptions, public institutions are hardly involved in the everyday implementation and governance of the local sustainability initiatives.

Table 5.2. Preliminary mapping of the actors and institutions that comprise the polycentric governance systems around the Dutch demonstrator.

Institutions and actors	Role in the local energy transition	Position in the SERENE project
Global Ecovillage Network	Platform to exchange experiences	None
European Union	Setting European objectives, rules and legislation	Project funder, via Horizon2020 programme
National government	Transposition of European legislation and designing support schemes	None
Netherlands Enterprise Agency	Implementing national policies and support schemes	None

Municipality Olst-Wijhe	Only involved when local energy infrastructure needs to be built on public land	None
Goed Veur Mekare energy cooperative	Local energy cooperative in Olst-Wijhe	Not directly involved, but members overlap with Aardehuis and Vriedenerf
Vereniging Aardehuis Oost-Nederland	Community of residents (prosumers) in Aardehuis	Key implementation partner, SERENE project partner
Vereniging van Eigenaren Vriendenerf Olst	Community of residents (prosumers) in Vriedenerf	Key implementation partner, external to SERENE team
Sallandwonen	Owner of three houses in Aardehuis community	None
Enexis	Grid operator	Communication attempts by project partners have failed so far
Loqio Services	Contractor for installation of smart technology and energy management systems	SERENE project partner
University of Twente	Research institution	SERENE project partner
Saxion	Research institution	SERENE project partner

Poland: Actors and institutions

In the Polish demonstrators, the Municipality (gmina) Przywidz plays the central role in both the implementation of the SERENE project and in any broader local energy system transition efforts (Table 5.3). It is not just the owner of the buildings that are targeted in SERENE interventions, but has also been the driving force behind local environmental initiatives and recently received an award for its ecological

activities. Together with the local grid operator, Energa-Operator, the municipality has also engaged in public outreach and community events on sustainability issues.

As a key activity to improve the interaction between local actors and institutions on the topic of renewable energy, the SERENE project partners are currently trying to revive the Zielona Brama energy cluster. This cluster was established a few years ago as a platform for business-to-business interaction on energy between companies in the region, following new national legislation introducing the energy cluster framework. There are no specific requirements regarding the governance structures within the clusters, putting a lot of emphasis on self-governance and self-organization among cluster members. Key actors indicated that there is already interest to revive the cluster by some local companies, however, the communication with the previous cluster administration has been difficult so far. Additionally, there is no clear plan yet on the specific role of the cluster in the local energy system transition and on what the involvement of different companies with the cluster could look like.

While there is very limited community organization on the topic of energy in Przywidz, key actors emphasized that it is important to have a strong network within the community by working with well-connected residents or informal community leaders. Having project team members who are also residents of Przywidz allows the SERENE project partners to gather important information and perspectives of local residents, and helps to spread the word about project activities to get residents interested and involved with the project.

Table 5.3. Preliminary mapping of the actors and institutions that comprise the polycentric governance systems around the Polish demonstrator.

Institutions and actors	Role in the local energy transition	Position in the SERENE project
European Union	Setting European objectives, rules and legislation	Project funder, via Horizon2020 programme
National government	Transposition of European legislation and designing support schemes	None
Zielona Brama cluster	Regional energy cluster for business-to-business exchange	None, but might be included later on
Municipality (gmina) Przywidz	Owner and manager of buildings; driving force for local environmental action, incl. energy	Key implementation partner, SERENE project partner
Energa-Operator	Grid operator	SERENE project partner
Stay-on	Contractor for installation and management of energy storage technology	SERENE project partner
GSJ	Contractor for installation of heat pumps	Hired by project partners
Local residents	Energy consumers	Involved via public outreach events
Institute of Fluid-flow Machinery / Instytutu Maszyn Przepływowych (IMP)	Research institution	SERENE project partner

Governance assessment priorities throughout SERENE

The more specific governance arrangements and emerging governance conditions related to individual SERENE interventions will only become visible over the course of the project implementation. The following is a brief summary of important governance issues to address through in-depth research throughout the project duration, and the overall patterns we expect to see across the three countries and demonstrators based on current knowledge.

Given that all demonstrators are subject to the same EU-wide objectives on energy system transition and emission reduction, we expect to see some similarity in the overarching targets and norms across the three countries. However, the differing national political landscapes, historical development and local perceptions in each demonstrator will also provide a variety of visions, discourses, norms and assumptions with regards to how decentralized and local energy should take shape. There will thus likely be a variety in rules and norms to which the projects of the demonstrator sites are subject and that will influence and be influenced by the implementation of different SERENE interventions.

Mechanisms to hold actors and institutions accountable if projects of the demonstrators do not fulfil their responsibilities will most likely differ across the demonstrators, depending on the composition of institutions and actors. In the case of Denmark and Poland, where public institutions are taking the lead in the implementation of SERENE interventions, we will probably see more traditional democratic accountability mechanisms, e.g., elections, in use. In the Netherlands, the driving forces are not public institutions. It will thus be interesting to observe whether novel accountability mechanisms are being developed.

Throughout the SERENE project, a key role is assigned to local action, and local actors are in the lead in all demonstrators. All demonstrators may, however, struggle with the fact that national and international (European) governance and policy are usually designed for one-size-fits-all energy projects, and do not take into account locality and site-specific circumstances. In addition, throughout the implementation of different SERENE interventions, it will be important to take the heterogeneous preferences and competencies of all local institutions and actors involved into account, regardless of which local actor is leading the process.

Related to the acknowledgement of local heterogeneous preferences and perspectives, the role of trust in the implementing actors and institutions needs to be assessed throughout the project. Where trust is lacking, mechanisms to enhance it need to be included in the project, for instance to allow for sufficient participation of various social groups, collective decision-making, equitable and transparent outcomes. These processes will be highly site-dependent, reflecting varying levels of existing trust based on previous experiences and the societal composition and structure of the demo site communities.

Lastly, the SERENE project and the demonstrators will benefit from an emphasis on experimentation and learning in terms of governance interventions and social innovations. This is already an ongoing process in the Dutch demo sites, considering that they involve communities that have already been experimenting and innovating within their own neighbourhoods for several years. There are less clear expectations for

the Danish and Polish demonstrators, where the opportunity for learning processes will, to some extent, depend on the flexibility of public governance structures.

5.4 Urban planning

Energy systems are an important component of urban planning, as they both use and form urban space and are of great importance as a primary need for society and economic growth. This is particularly important with regards to local, decentralized energy systems as we are envisioning them in the SERENE project. As parts of the urban space and the built environment, they are produced and governed in interaction with wider social, cultural, and economic processes.

5.4.1 Urban planning factors in the local energy transition

We identified three urban planning factors of importance for the local energy transition; they represent large urban processes and encapsulate a number of smaller elements. For the full literature review and argumentation on these factors, refer to Section 8.4 in the appendix.

First, local energy systems are part of the local conditions of spatial equilibrium and land-use competition. Urban areas are inherently interconnected, and an intervention in a certain neighbourhood, e.g., new decentralized energy infrastructure, can be accompanied by a range of positive and negative externalities (spill-over effects) within the same neighbourhood and other parts of the city, for instance connected to affordability, segregation, and environmental quality. This means that choices about local energy systems—e.g., source, distribution, locational configuration, pricing—affect and are affected by choices about other important resources—e.g., through zoning, land use planning, and related place-based regulation (Brooks, 2012; Glaeser 2007).

Second, multi-sectoral and multi-objective approaches are needed to successfully integrate energy and urban planning and improve urban quality of life and sustainability. There are different pathways to this integration, but they all commonly include a political vision and governance framework, active involvement of problem owners and citizens, integration of energy matters into wider issues of urban liveability, and suitable ICT and data management (Bossi, Gollner, & Theierling, 2020; Gollner et al., 2020).

Third, a paradigm shift from top-down urban planning towards an adaptive, bottom-up urbanism approach to place-making and everyday management of urban space is increasingly seen as an important component of sustainable urban transitions of all kinds, including local energy transitions. This is related to the ideas that if we are to hope for sustainable and resilient cities, citizens ought to be in the driver's seat of their own lived environment (van der Graaf, Nguyen Long, and Veeckman, 2021), and that urban planning for these cities needs to include a number of participatory, inclusive, and inherently community-based concepts (Petrescu et al., 2016; Seto et al., 2012).

5.4.2 Urban planning conditions in the demonstrators and implications for SERENE

Demographics and built environment

Here we first present the basic demographics of each demonstrator, including their local climate zone (LCZ) structure, as a comprehensive way to represent both social and physical structure of the communities (Stewart et al., 2014). The LCZ classification communicates the energy balance of different built-environmental configurations, which affects their maximum and minimum theoretical energy demand profiles, within which behavioral patterns of energy use will operate. We also briefly reflect on current practices related to energy, climate change adaptation and nature-based solutions in the context of urban planning.

In Denmark, the village of Hylke has a population of ca. 400 inhabitants and the village of Låsby a population of ca. 2,000 inhabitants. Their parent municipality of Skanderborg has a population of ca. 18,000 inhabitants. It is a rural area with predominantly low vegetation and some presence of forested areas and lakes. The population is dispersed across four main settlement areas of LCZ types 6 and 9, representing a sparse low-rise built environment. This corresponds to a controlled dispersion spatial planning paradigm (Figure 5.5). The specific demo sites in Hylke and Låsby are characterized by a high level of spatial control by the developer with a strong pre-programmed role of the RES where climate adaptation solutions are unclear. Thus far, it is unclear what the exact role (or flexibility) of dwellers will be in developing and applying nature-based solutions in public and private spaces in relation to energy.

In the Netherlands, the village of Olst, where both the Aardehuizen and Vriendenerf communities are located, has a population of ca. 5,500 inhabitants. It is a rural area dominated by low vegetation, scattered tree-covered areas, and river water. The population is concentrated in one main settlement of LCZ types 6 and 9, representing a sparse low-rise built environment. This corresponds to a concentrated development spatial planning paradigm with modest scattered development elements (Figure 5.6). The demo sites are characterized by the fact that a sustainability community is already in place, where climate change mitigation (energy) is one of the primary motivations, in the context of a more generic set of concerns and practices that connect to climate change adaptation. It is likely that adaptation-mitigation synergies in the environmental-energy planning domain are happening or will happen ad-hoc and at small scales, which is encouraging from the perspective of integrated urban commons and DIY sustainable urbanism.

In Poland, the municipality of Przywidz, in which all the demonstrator sites are located, has a population of 6,000 inhabitants. It is a rural area dominated by areas of tree-covered and low vegetation, with some presence of lake water. The population is concentrated in a few small settlements of LCZ type 9, i.e., a spare very low-profile settlement pattern with no clear spatial planning patterns (Figure 5.7).

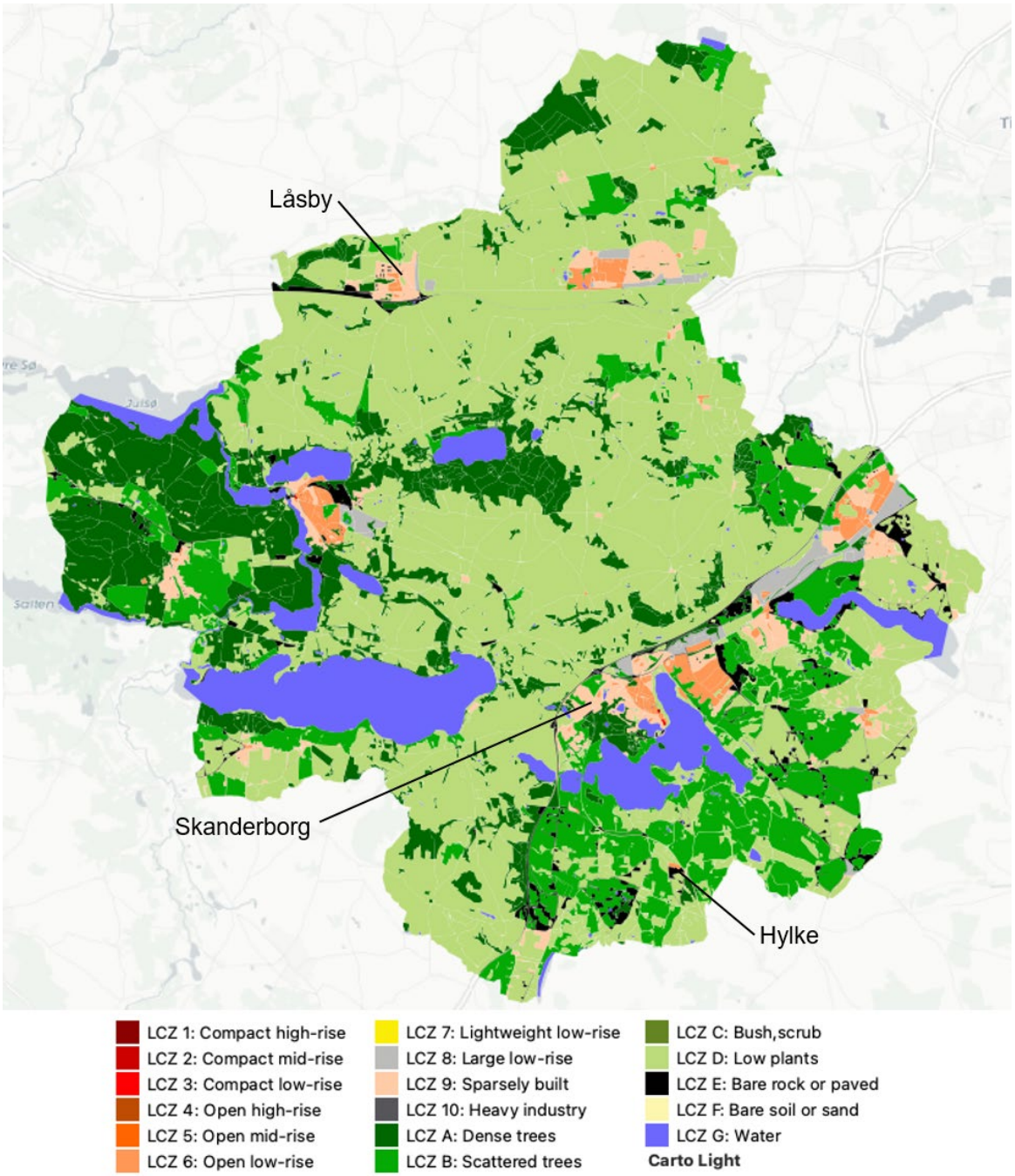

Figure 5.5. Local Climate Zone (LCZ) map of Skanderborg municipality. Produced with the Geoclimate algorithms of Lab-STICC (CNRS UMR 6285 - DECIDE team - GIS group) based on primary data by OpenStreetMap.

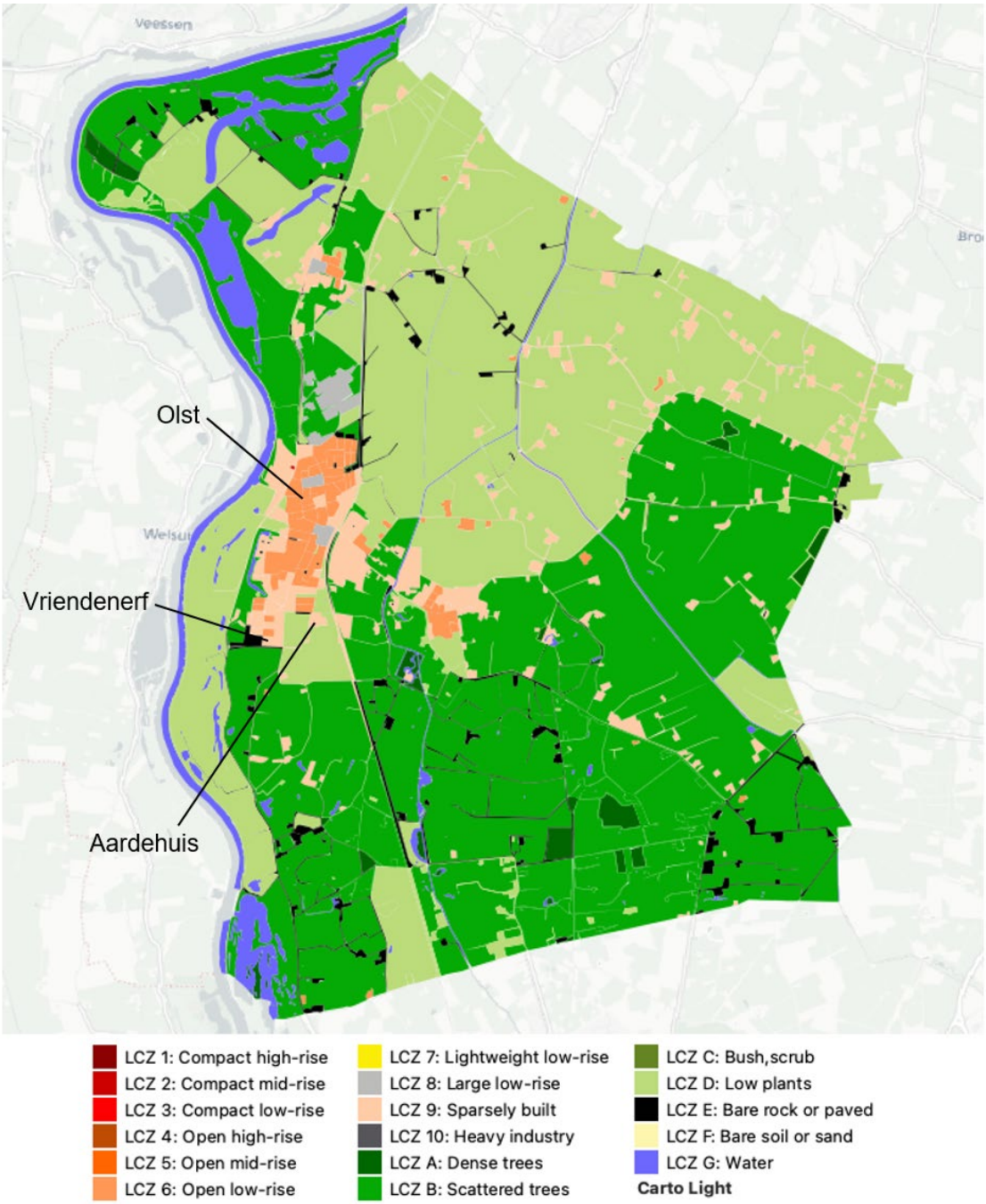

Figure 5.6. Local Climate Zone (LCZ) map of the village of Olst. Produced with the Geoclimate algorithms of Lab-STICC (CNRS UMR 6285 - DECIDE team - GIS group) based on primary data by OpenStreetMap.

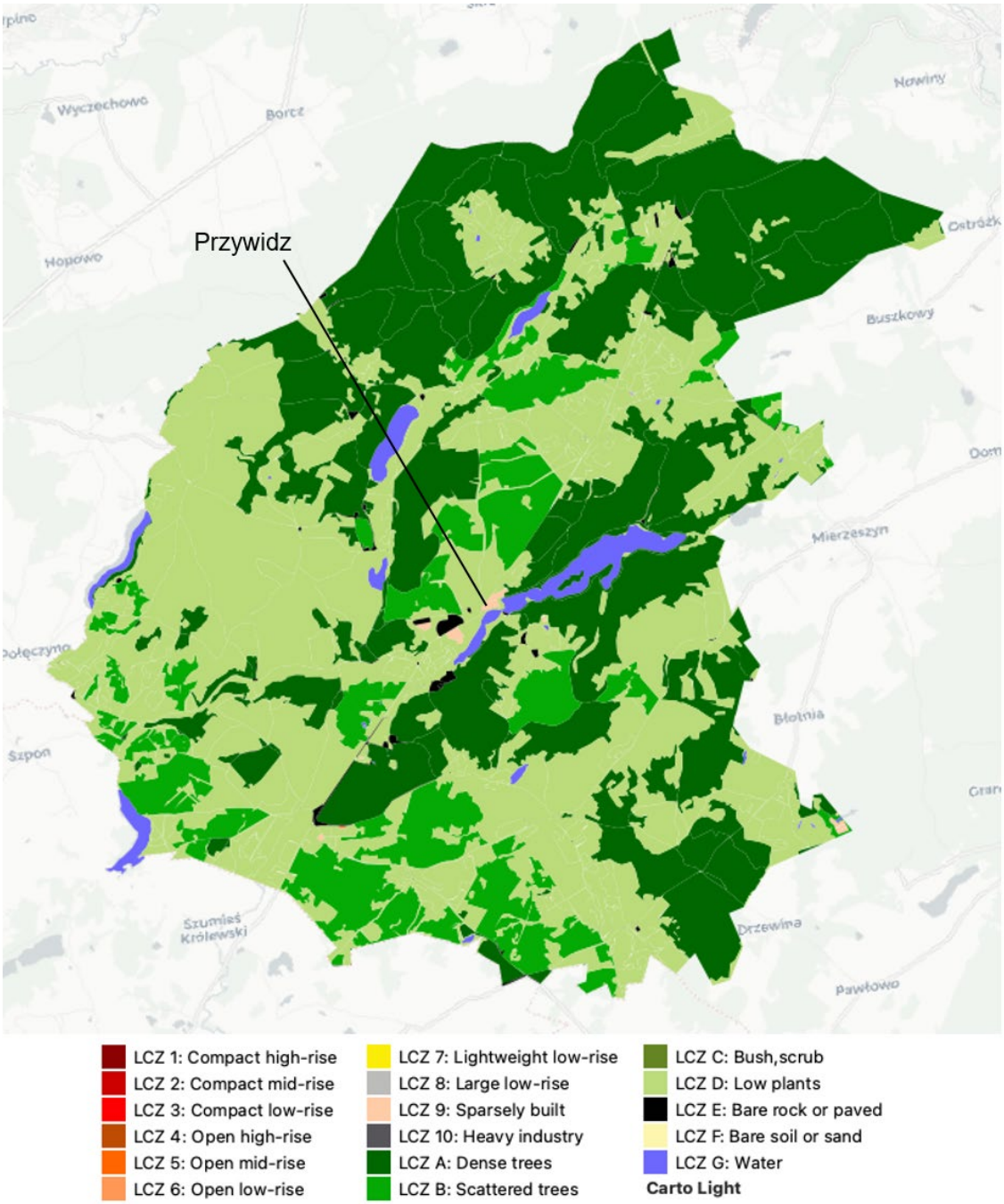

Figure 5.7. Local Climate Zone (LCZ) map of Przywidz municipality. Produced with the Geoclimate algorithms of Lab-STICC (CNRS UMR 6285 - DECIDE team - GIS group) based on primary data by OpenStreetMap.

A traditionally strong top-down approach to urban planning and urban management appears to be in place in this area. Local key actors mentioned some instances of loosely self-organized citizens, but it is unclear how this will materialize because of the long-standing expectation of a strong involvement of the municipality in strategy setting and the implementation of solutions. This might come in the form of large public projects, but that would imply fierce competition with other city-wide projects, where sustainability projects do not fare as well.

Local energy infrastructure and building characteristics

The preceding section presented population and settlement structure by using the local climate zone typology (Stewart et al., 2014) as LCZ is state-of-the-art for combining urban planning with energy balance and microclimate studies. It should be noted that local climate zones do *not* communicate the local physical climate and meteorological patterns, but key urban form parameters that affect the energy balance of a settlement. All demonstrators are notably rural, which should be the prime determinant of energy demand depending on season and climate. However, there are differences in the regional and local settlement structures, as well as the population numbers distributed over this structure, that are translated into differences in their energy demand profile and integration of climate change adaptation-mitigation profiles. Given this spatial planning context, below we provide a more detailed look into the very local scale and the site and building characteristics.

Across the entire area of Skanderborg municipality with its 62,000 inhabitants, ca. 44% of the total energy consumption and ca. 55% of the total electricity consumption stems from RES. Local renewable electricity production infrastructure includes 17 wind turbines, producing 68 TJ in 2017, and PV installations on ca. 1,500 houses, producing 1.6 TJ in 2017. The local heating infrastructure combines three types of heating: 1) district heating, based on biomass, waste or heat pumps, which accounts for 68% of all heating, 2) individual gas boilers connected to the gas grid, which account for 15% of all heating, and 3) individual heating systems based on other energy carriers, including oil boilers, individual heat pumps, solar thermal systems and wood pellets boilers. The demo sites in Låsby and Hylke fall within the third category (i.e., no district heating), and the SERENE project is aiming to find green individual heating solutions that can later be replicated to other villages where district heating is not feasible. The expansion of district heating systems is difficult, as they commonly need to serve at least 70% of houses in their catchment area to be economically feasible. This means that if local residents are impatient and buy their own individual heat pumps instead of waiting for district heating, the latter will not succeed.

The existing buildings in the demo site in Hylke and the planned new development in Låsby were described by local key actors as “standard houses,” i.e., not constructed according to any specific ecological or low-energy building standards. The construction of communal heat pumps within SERENE might provide the opportunity to implement some nature-inspired infrastructure elements to shield residents from externalities, particularly noise pollution, but this has not been decided yet.

The two demo sites in Olst meet their energy demand from local renewable energy generation, including approximately 126 MWh per year in electricity from PV installations, and approximately 360 MWH per year in heat from heat pumps, wood boilers and solar thermal systems. Additionally, both sites are built according to different eco-building standards. Aardehuis was constructed following the earthship concept, a set of circular and bio-based principles that was adapted to the Dutch context by a Dutch architect. The six Earthship principles are: 1) thermal or solar heating and cooling, 2) solar and wind electricity, 3) building with natural and recycled/repurposed materials, 4) contained sewage treatment, 5) water harvesting, and 6) food production (Vereniging Aardehuis, n.d.; Earthship Biotecture, n.d.). The houses in Vriedenerf were built according to nearly zero-energy building standards and with the goal of covering the entire energy demand of the building with its own energy production from RES. This is

achieved with a combination of energy efficiency measures and energy generation facilities like heat pumps and PV installations (Vereniging Vriedenerf, n.d.).

In Przywidz, the municipality is currently implementing projects to increase amount of PV installations, with the goal of having approximately 400 PV installations within the municipality. A local private PV installation with a capacity of 500 kW is additionally planned. This puts PV use in Przywidz far ahead of the average among Polish towns and villages of similar size. There is no heating or gas network in the municipality, instead, each building has its individual heating system. The vast majority of private houses use coal ovens to heat their homes, with some other private houses using gas boilers with their own gas tank or biomass, and a few instances of solar thermal systems. Fourteen heat pumps provide heating to municipal buildings.

Electric mobility

In all three countries, SERENE will include interventions to expand electric vehicle (EV) infrastructure and utilization, which is currently very limited in all demo sites. Transport and mobility patterns will play an important role in the optimization of the collective energy demand of each area, but the degree to which local residents are open and able to change their mobility patterns differs from country to country. To provide some context for the planned EV interventions, it therefore makes sense to briefly look at EV and mobility patterns in each country. Recent data on newly registered electric and hybrid passenger cars across the EU show that in 2020, more than a quarter of new cars in the Netherlands were electric or hybrid vehicles, with a strong focus on fully electric vehicles. At the same time, 16% of new cars in Denmark and only 2% of new cars in Poland were electric or hybrid (Figure 5.8). This indicates that the further expansion of EV mobility will probably be much easier in the Netherlands than in Denmark or Poland.

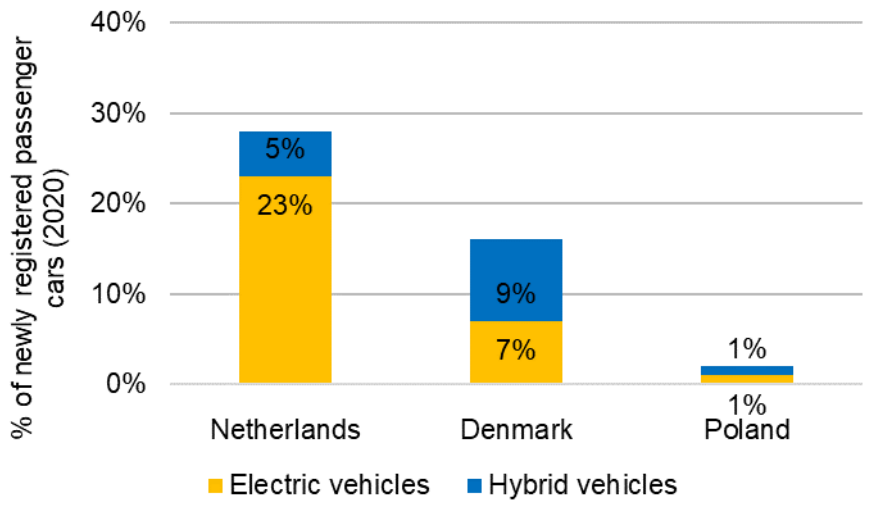

Figure 5.8. Newly registered electric or hybrid passenger cars in 2020 for the Netherlands, Denmark and Poland. Data source: European Environment Agency (https://www.eea.europa.eu/data-and-maps/figures/new-electric-vehicles-by-country).

Urban commons

As part of a more general approach to energy commons and shareable cities in each of the demonstrators, the urban commoning potential refers to the way in which the local community is, formally or informally, organized and deciding upon neighbourhood common spaces from the perspective of energy, as well as how they use and manage those spaces. This also includes how energy is approached as a common good, and how spaces and infrastructure are approached and managed, ultimately describing what bottom-up adaptive management and re-planning of the neighbourhood looks like.

In the two Dutch demo sites, Aardenhuis and Vriendenerf, urban commoning is already a key element of the two overall neighbourhood projects, including for instance community gardens, communal maintenance of green spaces and an EV charging station in the neighbourhood. Here, it will be interesting throughout the SERENE project to track how the existing urban commons capital ties up with the municipality and the private sector, as these two actors become key success or failure determinants as urban common communities evolve through time. In the context of the relationship between the local energy commoners and the public and private sectors, energy as a non-market good is still problematic.

In the Polish and Danish demo sites, there is very limited or no social organization towards urban commons within the communities. Ongoing projects, including SERENE, are championed by the municipalities, but the institutional contexts are not those typically found in urban commoning initiatives. It will therefore be interesting to observe whether SERENE can create urban commoning potential in a context where either the developer has a high level of spatial control (Denmark), or the municipality is expected to plan, implement and manage solutions (Poland). Nevertheless, the Danish cases are promising due to a long precedent of community participation in Nordic urban planning paradigms (see for instance Haarstad et al., 2021), whereas in Poland, the rising obstacles in energy security might provide an effective motivation to kick-start energy commons thinking.

Given the above conditions in the different demonstrators, careful analysis of their urban planning and urban commons trajectories throughout SERENE can create new knowledge on local energy communities, their climate resilience and adaptive capacity in an urban planning context. Regarding energy commons, Foster and Iaione's (2019) framework provides three dimensions which can be tracked to understand the kind of commons-based self-organization in which the demonstrators develop their adaptive capacity and climate resilience profile: 1) the value (and goods, services) that is generated by the treatment of energy as a peer-to-peer common good, 2) the bottom-up collective governance approach that is adopted by the community, and 3) the role of the public and private sectors as enablers or obstacles to energy commoning activities.

With respect to a broader urbanism perspective, a set of dimensions emerge that can eventually lead to a taxonomy of local energy communities from an urbanism perspective. These are:

- Single-actor versus multi-actor process of planning urban space;
- Top-down versus bottom-up stances on urbanism;
- Distribution of local RES across public and private space;
- Level of spatial control of dwellers in private and public space;

- Location and land use context;
- Transport modes and mobility patterns;
- Hierarchy of values and preferences surrounding urban well-being;
- Climate change adaptation and mitigation integration.

5.5 Social acceptance

In order to ensure public support and buy-in for the local energy transition, interventions need to confront questions of social acceptance, i.e., how the public perceives and reacts to technological and structural changes in the energy system. A potential lack of social acceptance has been identified as one of the key barriers to renewable energy transitions in Europe (Segreto et al., 2020). Throughout SERENE, it is therefore important to account for the current attitudes towards technological and social innovations in the demonstrator sites and potential changes in attitudes throughout the project.

The term 'acceptance' as we are using it here broadly discusses people's perceptions, attitudes, and thoughts towards a social transformation of energy, and the processes of public involvement and people's reactions.

5.5.1 Social acceptance factors in the local energy transition

We identified three social acceptance factors of importance for the local energy transition. For the full literature review and argumentation on these factors, refer to Section 8.5 in the appendix.

First, the social or public acceptance of the local energy transition captures the level of tolerance towards social aspects of energy transitions, such as equity, democracy, and sustainability among the public. This social acceptance tends to be primarily structure- and path-dependent within a society, rather than dependent on the individual status and agency of its citizens (Seidl et al. 2019).

Second, the technological acceptance of the local energy transition is predominately focused on the acceptance of new technologies and gadgets related to decentralized energy production and digitization. Such technologies can be linked to sensitive personal issues such as health, privacy, and security. Where concerns go unaddressed, they may even spark movements against technological transitions towards smart energy (Lee and Hess 2021; Hess and Colely 2014).

Third, opportunity structures determine whether a system is conducive to the emergence of social movements that can bring about structural changes and affect public perception and acceptance of energy transitions. Understanding opportunity structures has been particularly important in predicting organizational, institutional, and individual behaviors in relation to energy transitions, such as in the case of the development of France's civil nuclear program (Schweitzer & Mix, 2021).

5.5.2 Social acceptance conditions in the demonstrators and implications for SERENE

<u>National-level social acceptance and experiences with renewable energy systems</u>

Country-wide levels of environmental awareness and experiences with decentralized or renewable energy technology can provide a first baseline for the expected level of social acceptance in the demonstrators, and highlight a stark difference between Denmark and the Netherlands on one side and Poland on the other. While Denmark and the Netherlands already have strong environmental movements, with public

participation and citizens taking up the role of electricity prosumers by investing into small-scale PV installations, the sustainability debate in Poland is still in its early stages (Steciag, 2010; Krzywda et al., 2021). However, recent surveys have seen a significant increase in environmental awareness among the Polish population, particularly in urban areas (Bieńkowska et al., 2021).

Regarding prior experiences with different energy technologies, Denmark has established itself as an international frontrunner on district heating, serving 64% of Danish households in 2019 (Johansen & Werner, 2022; Jensen, 2019). Over the past decades, district heating has become the preferred way to receive heat in Denmark, being seen as a very reliable technology. The same is true for heat pumps, which will be used in the Danish SERENE demo sites and have particularly become more attractive in light of the recent increase in energy prices. Denmark additionally already has a lot of experience with distributed electricity production and the balancing of different forms of energy use, and discussions on small-scale pricing in the energy sector are currently ongoing. The Netherlands have similarly expanded decentralized energy production over the past decades, with a strong focus on smart grid management in recent years. This has led to a re-shuffling of market actors in the Dutch energy sector, including the distinction between grid operators and energy producers and the increasing role played by energy cooperatives, energy service companies and aggregators, which has strengthened the position of individual households as prosumers within the Dutch market and has made household-level energy production more attractive (Verkade and Hoffken 2018).

In Poland, electricity has historically been centralized, whereas heat has been decentralized, primarily in the form of individual coal ovens in each house. The latter is seen to provide households with a measure of independence, not having to rely on central, potentially state-owned infrastructure to heat their houses. Accordingly, while a number of measures to decrease CO2 emissions in Poland received broad agreement in a recent survey, measures that would reduce the production or access to coal were seen less favourably (Bieńkowska et al., 2021). However, key actors involved in the Polish demo cases expect the current surge in coal prices in Poland to lead to a shift in attitudes here. Decentralized renewable energy technologies like heat pumps or PV have been a relatively new phenomenon throughout Poland and are still met with skepticism by a significant amount of people.

Social acceptance in the demonstrators

Zooming in on the situation in the different demo sites, we can observe a significant difference between the two Dutch demo sites, which are eco-housing projects developed by or with the residents, and the demo sites in Denmark and Poland, which are regular housing projects without input from the current or future residents. More specific information on local attitudes and social acceptance of renewable energy technologies was provided by key actors involved in the different demo sites.

In Olst, the two demo sites Aardehuis and Vriedenerf are community-led eco-housing projects, including an emphasis on green building techniques, resource re-use and renewable energy production. Support for the local energy transition as it is envisioned in SERENE is therefore already strong throughout both communities. It is noteworthy that prior to Aardehuis and Vriedenerf starting their activities, there had been no experience with energy decentralization or ecological building in the region, and the respective

communities had to learn much along the way, including how to balance environmental idealism with pragmatism and practicality in building their own neighbourhood.

In Skanderborg, municipal statistics on RES show that 44% of all energy consumption and 55% of electricity consumption is currently sourced from renewable energy resources. This indicates a significant support to the use of or transition towards RES. This support, however, is not primarily motivated by environmental awareness and sustainability, but by the relatively low prices for RES. Additionally, local informants indicated that residents value convenient energy solutions that do not require them to engage in significant operation and maintenance activities, but rather allow them to outsource these responsibilities to an external provider, as is the case for district heating.

In Przywidz, environmental awareness is primarily linked to a fondness of the local environment – the town is located near a picturesque forest and lake – and the local tourism industry, which depends on ample snowfall in winters and has been negatively affected by the intensification of climate change over the past years. Beyond these concerns, there are no larger discussions on sustainability or ecological issues. With regards to new technologies, similar to Skanderborg, local residents value cheap and low maintenance applications. The willingness to actively look into and engage with new technology related to energy production from RES is relatively low, and the ideal system for many residents would be automated and require no active involvement or monitoring. In addition, new technology should be tried and tested before people are willing to engage, highlighting the importance of local technology trendsetters who can provide examples for the community and show that new technologies indeed work and can save money.

Individual-level acceptance

The above insights provide an important baseline on the local reactions to different technological and social innovations within the SERENE project. It should be noted though that they can only provide an indication, but no definitive information, due to the so-called 'general-local gap' of technological acceptance, which refers to the observation that the overall acceptance of a new technology is usually higher than the acceptance of a specific project related to the implementation of the technology on the local level. This is not necessarily due to 'not in my backyard' (NIMBY) attitudes, but rather linked to other factors that might play a role in the local implementation, such as funding or the actors involved (Baur et al, 2022; Upham & Johansen, 2020). Consequently, the implementation of different SERENE innovations might still encounter unforeseen resistance that is unrelated to specific technology.

Throughout the SERENE project, it will be important to assess acceptance on the individual level across all demo sites, including residents' current attitudes towards various technological and social interventions and towards new actor roles, as well as changes to these attitudes over the course of the project. For this purpose, the project team will conduct several surveys in the demo sites that collect demographic and household characteristics, individual behaviour, attitudes and concerns towards local energy transitions and climate change. Key research questions related to these surveys and social acceptance include:

- What is the relationship between behaviour and specific characteristics on the individual level and on the household level?
- How do demographic characteristics influence people's opinions on energy and climate issues?
- How do local residents understand and perceive the importance of the SERENE project?

Next to supporting the implementation of SERENE innovations, these questions will also create new insights on local energy transitions that can be useful to future transition projects.

Additionally, experiences from the demo sites throughout the SERENE project can provide new insights on key drivers of change in social acceptance. Two aspects that have already been shown to play a role in individual or public acceptance are (1) the strong increase in energy prices, particularly for fossil fuel-based energy, linked to major geopolitical events, and (2) the role of the recent EU energy directives in opening up spaces for new forms of energy communities. Further research on these and potential other aspects will be needed to draw conclusions on their role in the local energy transition.

5.6 Societal debates

Over the course of the local energy transition towards decentralized, renewables-based energy systems, the role of different stakeholders within the system and the way in which they interact with the system and each other will change. The implementation of infrastructures for local energy sharing and trading in the energy sector, especially in the context of local energy communities, will create new stakeholder networks and relationships. Through disintermediated and decentralised energy structures, local communities have the potential to develop forms of self-sufficiency for the ways in which energy is produced, shared and managed in their community (Martiskainen & Watson 2009; Mengelkamp et al. 2018).

With the increased involvement of citizens and local communities in local energy systems, societal discourses and socio-technical imaginaries, as well as their materialization in society, will shape how the energy system transition is perceived and discussed. Socio-technical imaginaries are defined as "collectively imagined forms of social life and social order reflected in the design and fulfilment of nation-specific scientific and/or technological projects" (Jasanoff & Kim, 2009, p. 120). Understanding such cognitive structures and stakeholders' views, ideas, interests and visions of future energy systems will increase the likelihood of a successful system transition (Kern & Rogge, 2018; Sovacool, 2019).

5.6.1 Societal debate factors in the local energy transition

We identified three societal debate factors of importance for the local energy transition. For the full literature review and argumentation on these factors, refer to Section 8.6 in the appendix.

First, novel stakeholder arrangements, societal practices and forms of governance will emerge throughout the energy system transition, influencing the agency of different energy stakeholders and the interactions between them. This particularly applies to the formation of local energy communities, in which citizens often take a much more active role, and necessitates an examination of how the power relations and forms of governance between citizens and other energy sector stakeholders are influenced (Ahl et al. 2019; Li, Bahramirad et al. 2019; Lowitzsch et al. 2020; Mengelkamp et al. 2018).

Second, discourses and societal debates between different stakeholders shape the way in which local energy systems are perceived and energy realities constructed, based on varying sets of ideas, concepts, categorizations, values, social circumstances and so forth (Lassen, 2016; Wagenaar, 2011). Discourses are outcomes of discussions and deliberations between actors and their interpretations. Consequently, local energy system transitions must deal with the interplay and societal debates between actors, institutions, regimes and landscapes and the continuous re-enactment, re-interpretation and re-negotiation of arguments enshrined in different discourses (Brugger & Henry, 2021; Hajer & Versteeg, 2005).

Third, the acknowledgement of socio-technical imaginaries, i.e., the ways in which science and technology are viewed and legitimized as contributing to a society of the future, is important for the introduction of new technologies into a society (Eaton et al., 2014; Jasanoff & Kim, 2009). Such narratives can stimulate coalition-forming and resistance to existing governance structures, in support of local socio-technical system change.

5.6.2 Societal debate conditions in the demonstrators and implications for SERENE

Throughout SERENE, project implementation needs to take note of the initial state and further development of social organization in the demonstrators' communities, as this will play a crucial role for community participation and shape societal debates on the project itself and the local energy system transition at large. This builds on previously outlined information on actors and institutions, as well as the community organization structures already in place in each demonstrator. It also includes questions such as who is included in meetings on energy, what kind of incentives are given to encourage participation, and whether meetings are organized in an inclusive and accessible way, e.g., related to the meeting location or time of the meeting.

In addition, the content of current and future societal debates and arguments on the local energy system will affect attitudes towards energy transitions and the SERENE project. Consumers' decisions about energy sources and prosumerism do not only depend on a moralistic climate change perspective, but also have economic, social, cultural or aesthetic components. These conglomerates of arguments and visions of future worlds need to be mapped and be known to actors driving local energy transitions.

Below, we sketch out what is known on current social organization and the different positions in the societal debate about the local energy transition in the demonstrators. We also highlight a number of aspects that will be important to analyze as societal debates develop throughout the SERENE project.

<u>Denmark: Current situation</u>

There is relatively little information available on social organization in the Danish demo sites as of now. Part of this is due to the fact that the planned SERENE interventions in Denmark predominantly target building developers and owners of existing buildings, rather than the tenants or the larger local community. As such, key actors have been focused on the interactions with these parties. Additionally, one of the two demo sites is a new development, meaning there simply are no tenants yet. It is therefore difficult to establish a baseline of social organization or societal debate positions on the local energy transition within Låsby and Hylke at this point. The SERENE surveys that will be conducted in the different demonstrators will be able to provide insights.

We can also draw some lessons from larger discourses on local energy systems in Denmark. The general discourse here is one that prioritizes sustainability, but not at all costs. Rather, there is an economic understanding that investments in the energy system should bring some returns, both on the large, regional scale and for small-scale household-level investments. This is reflected in the way that the SERENE cases are envisioned, namely as a kind of market mechanism, in which tenants buy renewable energy from the microgrid, with the municipality or any other local government not playing any role in this arrangement. According to Danish key actors, Danes see the future as increasingly gas-free, electric and organized on district level, to a large part due to the recent geopolitical developments. However, it is not clear whether this is primarily a view of SERENE project partners, or of broader societal groups. Thus, district heating is mentioned as a proven technology that has some level of control for households. People have developed trust in the technology as well as the expert system surrounding it, and enjoy the system's convenience.

Netherlands: Current situation

The community-led nature of the Dutch demo sites goes hand in hand with a significant degree of social organization that is already in place. In the case of Aardehuis, for which information was provided by local key actors, the community has formed four working groups in which residents are working on the neighbourhood's green spaces, energy, finances and communications. Working group coordinators serve as a sort of spokesperson for the community on their specific issues and in contact with external partners. Monthly community meetings provide space for the exchange of ideas and decision-making. According to key actors, the meetings follow a sociocratic decision-making model, i.e., decisions are sought to be made based on consensus rather than majority vote. While participation in the meetings is not mandatory for residents, important decisions require the attendance and participation of at least half of the community.

The key actor interviews on Aardehuis also showed that the community is characterized by an ambitious energy transition discourse, which has begun as very much idealism-infused, but shows signs of social learning towards realism and pragmatism in some aspects. The original ambitions of the neighbourhood were to 1) become self-sufficient also in terms of energy, 2) share any surplus renewable energy generated, 3) share their experiences in a lifestyle at the forefront of the energy transition, and 4) develop sustainable building networks and expertise by maintaining contacts with architects, contractors, experts, and collaborative municipalities. Once energy self-sufficiency was achieved, the focus of the discourse and activities turned outward to see how the community could help others. This is highlighted by the importance of outreach activities, including guided tours through the neighbourhood. The community perceives its energy surplus in the neighbourhood not only a technical issue, but also as a social one. The inhabitants are keen on sharing their experiences and not be seen as some strange group of people living in a way that is only for few people. Besides that, there seems to be a technology-focused discourse when it comes to the energy system, as upcoming technologies are anticipated with a positive outlook and trust in the experts guiding the transition locally. It turned out that the discourse in the community has become more realist, as practical experiences within the Dutch regulatory framework led them to adjust their short-term goals on energy storage to the mid-term.

Poland: Current situation

Przywidz does not have any specific community organization on the topic of energy. Residents only really gather to discuss energy-related topics during municipal meetings, meaning the municipality organizes the meeting, leads the discussion, sets the agenda, and provides incentives for local residents to attend, e.g., offering free food. However, these meetings are often not focused on energy issues alone either, but rather broader meetings on environmental topics in general or to celebrate a specific event, e.g., a new electric bus service. Additionally, meetings are usually primarily informative and do not involve structured interaction or discussion with local residents, and are, by some, perceived to have political undercurrents, as the mayor's political party will usually be present.

Local key actors indicated that while there is no community organization on energy, there are a range of clubs and associations related to hobbies and social issues in Przywidz which could provide initial venues for energy-related discussions, particularly in the context of shared concerns related to rising energy prices. There are also currently no specific community leaders, including no influential traditional

community leaders like priests, but a number of well-connected residents who can be quite influential within their own networks and would thus be useful to collaborate with for public outreach activities.

In general, there is an interest in the environment, primarily related to nature and biodiversity issues, not so much climate change, but this does not hold for all inhabitants. Community, sharing, collective culture, and collective problems seems to play a marginal, if not absent, role in the local discourse, as people are to themselves and are busy with maintaining their own quality of life. Municipalities are perceived as caretaker; people look to the municipality to help them with retro-fitting their household energy system. Regarding energy initiatives, there is a relatively strong attitude of waiting and seeing how functional technologies will be before joining an initiative. This is currently fueled by uncertainties surrounding new energy laws and regulations. There also seems to be some distrust in larger-scale energy initiatives that resemble NIMBY attitudes, e.g., with constructing windmills for energy production.

Energy technologies are mainly seen from a finance perspective. Thus, rising energy prices, including coal, are an important factor for a positive view on renewables. There even seems to be panic on the market currently given gas and artificial coal shortages. Smog has figured as a prominent environmental hazard in the region's discourse, but has reduced after industrial renewal or discontinuation. While a climate change debate seem to be mostly absent on both the local and the national level, the shrinking tourism revenues due to lower snow availability in the region does worry people and increases the feeling of nostalgia. However, a distinction has to be made between generations in this, as younger generations are more aware of the issue and value a beautiful landscape, partly owing to ecology classes at schools.

Development of societal debates throughout SERENE

In order to cause a lasting local energy system transition as it is envisioned in the SERENE project, it will be important to engage local citizens in all demonstrators and motivate them to take an active interest in their energy supply. This also includes opportunities for citizen participation in the different SERENE interventions and the overall project process in each demonstrator. Implementation partners will need to navigate the tensions between different energy and environmental discourses and socio-technical imaginaries on the local level, and find suitable ways to engage local communities.

More specific issues to take note of throughout the implementation of SERENE include discourses related to investments in green infrastructure (as opposed to investments in other issues), and the effects of the recent EU energy directives in shaping discourses related to the notion of energy communities on different levels and relative to the goals of the SERENE project.

6 Conclusion

This report considered the non-technological dynamics of energy transitions which might play a role for the implementation of local citizen-centered energy systems in the SERENE project. Specifically, it addressed the question: *Which socio-economic, governance and regulatory factors influence the local energy system transition?*

In order to better understand such dynamics, we conceptualized the local energy system transition as a socio-technical system change. Given that the local energy system comprises both technical and social elements, system change includes the co-evolution of both types of elements. Our analysis is particularly based on two key concepts from the transition management literature: the multi-level perspective (MLP) theory and the strategic niche management (SNM) theory. They take an integrated perspective on sustainability transitions, which helps us to account for social system elements and dynamics in the local energy system transition.

We then applied six different social science perspectives to map the social factors that may affect the local energy system transition and identified implications for the different demonstrators and the implementation of the SERENE project (Table 6.1). *Socio-economic factors*, including the personal circumstances and motives of individual citizens and the interactions between technology and the energy market, influence energy consumption patterns and can create incentives for investments in the local energy system. *Regulatory factors* are predominantly related to the mismatch between the existing regulations, which were originally designed for fossil fuel-based energy systems, and the regulations needed to facilitate local energy systems based on renewable energy sources, including corresponding market regulations. *Governance factors* cover a range of factors related to the polycentric nature of energy governance, with transition processes including various institutions and actors across different levels, each of which may influence the local energy system transition. *Urban planning factors* revolve around the decentralized local energy system as a new contender for urban land use, and the need to integrate energy and urban planning in multi-sectoral and multi-objective considerations. *Social acceptance factors*, related to people's perceptions, attitudes, and thoughts towards a social transformation of energy, determine likely positive or negative community reactions to the local energy system transformation. *Societal debate factors* reflect on the changing role of citizens in the local energy system transition and cover issues related to notions of discourse, socio-technical imaginary and citizen empowerment.

Throughout the report, it has been clear that there are significant linkages and overlap between the six social science perspectives. This includes, for instance, the social movements and community organization structures that might be needed to push for change in regulations or formal governance arrangements. Similarly, social and technical acceptance for energy transitions or specific technologies are most likely to be achieved through effective societal debates and opportunities for active participation and experimentation. The inclusion of a broad range of stakeholders that exceeds the mere information or consultation level is central to socio-technical change. This requires appropriate institutional structures which allow for this level of involvement and participation, mechanisms to ensure that all stakeholders

have the means and possibility to participate, and a community that is motivated to engage with or even take leadership in local energy transition processes.

The broad mapping in this report gives a first overview of social factors that may influence the local energy system transition envisioned in SERENE, and the current situation in the different SERENE demo sites. It also creates the baseline for a follow-up report (SERENE project deliverable 3.2), which analyzes the obstacles related to these factors. Deliverable 3.2 particularly focuses on potential obstacles and necessary conditions related to four key dimensions of the local energy system transition: technological, socio-economic, environmental, and institutional. Taken together, the two deliverables thus provide a foundation for the active consideration of social factors in SERENE, including accounting for obstacles to the implementation of specific technical or social innovations and to the overall local energy transition, as well as minimizing unintended societal side effects of innovations, e.g., the marginalization of vulnerable groups.

Table 6.1. Summary of social factors that can influence local energy system transitions, and their most important implications for the SERENE project and implementation processes in the demonstrators.

Social science perspective	Factors that can influence local energy transition	Key implications for SERENE project and demonstrators
Socio-economics	• Individual socio-economic circumstances • Personal motives and ideals • Interaction between technology and market conditions	• Community survey needed for data on individual socio-economic circumstances and motivations of local residents • Presence or absence of different incentives for energy transition • Local energy poverty conditions and vulnerabilities • Opportunities for paradigm shifts

Table 6.1 continued

Social science perspective	Factors that can influence local energy transition	Key implications for SERENE project and demonstrators
Regulations	• Fit between existing regulations and regulations needed for new local energy system transitions • Flexibility of laws and regulations • Laws and regulations that keep up with the fast development pace of technical and social innovations • Regulation of energy markets and actors	• Regulatory uncertainty due to incomplete transposition of EU energy directives • Right of EU citizens to choose their energy supplier • Opportunities linked to 'regulatory sandboxes' in Dutch and Polish demonstrators • Specific regulatory conditions linked to individual interventions and actors
Governance	• Overlapping institutions and actors at multiple levels, each with some degree of autonomy • Self-organization resulting in patterns of ordered relationships between institutions and actors • Presence of overarching formal and informal rules and norms to align objectives and conflict resolution • Existence of conventional and unconventional accountability mechanisms • Valuation of local collective action • Recognition of site-specific conditions • Emphasis on experimentation and learning at different levels • Presence of trust and mechanisms to enhance trust across scales and levels	• Role of different actors and institutions in the local energy transition processes in the demonstrators, and match between this role and their position in SERENE • Emerging self-organization • Opportunities for active participation of local residents • Heterogeneous energy visions and preferences throughout project implementation

Table 6.1 continued

Social science perspective	Factors that can influence local energy transition	Key implications for SERENE project and demonstrators
Urban planning	• Spatial equilibrium and land-use competition between users • Consideration of multi-sectoral and multi-objective issues • Shift from a top-down paradigm to a more adaptive and bottom-up view on urbanism	• Capacity of current local energy infrastructure • Expansion of electric mobility • Urban commoning potential and trajectories throughout project implementation
Social acceptance	• Social or public acceptance as tolerance towards different aspects of local energy transitions • Technological acceptance of new technologies and gadgets related to decentralized energy production • Opportunity structures for social movements	• Prior experiences and acceptance patterns in the demonstrators • Changes to social acceptance through interventions or community movements throughout project implementation • Insights on individual-level acceptance require community survey
Societal debates	• Novel stakeholder arrangements, societal practices and forms of governance • Interplay, discourses and societal debates between actors, institutions, regimes and landscapes • Acknowledgement of socio-technical imaginaries	• Social organization in the demonstrators on energy and other issues • Role of current energy and sustainability discourses for project implementation • Influence of SERENE interventions on local energy discourses and debates

7 Reference list

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8 Appendix – Extended literature review on factors influencing local energy system transitions

8.1 Socio-economics

Authors: Cihan Gercek, Goos Lier, Joey Willemse

A range of socio-economic factors play a role in the way in which energy is used (Koirala et al., 2016). A distinction can be made between factors that have to do with the circumstances in which a person finds themselves, and factors related to personal motives (ideals). Socio-economic factors may additionally interact with technology and market conditions, as changes in technology and market conditions make new forms of behavior feasible.

The circumstances in which someone may find themselves include factors such as the distinction between rent versus purchase, rent with or without energy costs, the income situation and the income situation in relation to the energy consumption of the home. The personal motives (ideals) cover, for instance, the degree of willingness to pay extra for collective sustainability interests. The interaction between behavior versus technology and the market involves forms of decentralized energy generation and the possibilities of influencing people's energy consumption in smart ways.

A well-paid expat who has been able to temporarily obtain a house, all inclusive, in the center of a large city is in a completely different position to someone who is dependent on social security and who lives in a drafty house in a village. It will be clear that a rental contract in which the energy is included gives the tenant little incentive to cut costs, but the situation may be different for the landlord. Rental contracts on an energy-exclusive base involve a so-called *split incentive effect* (Koirala et al., 2016; Aydin et al., 2019; Dyson et al., 2010*)* An investment by the landlord in insulation measures usually only returns after complicated consultation in the form of a higher rent. Circumstances may also be such that there is little choice for families. Energy poverty means that, as a result of the high energy bill, people are left out in the cold or otherwise must cut back on necessities (Churchill & Smyth, 2021; European Commission, n.d..; Mulder, Longa, & Straver, 2021). Regarding energy poverty, a distinction can be made between acute problems resulting from rapidly rising energy prices, and the investments that must be made to achieve structural adjustments in connection with the energy transition. In the latter case, it may be that self-recovered investments cannot be made as if they were made, because there are no financing options (no possibility to borrow).

When discussing the circumstances, it was implicitly assumed that people are mainly guided by their own spending options. That is often the case. However, for a part of the population, there is a willingness to pay more or make more effort for environmentally responsible energy and other additional local collective interests (Koirala et al., 2016). Local initiatives involving cooperation with neighbors or like-minded people within a region are an incentive in this regard (Knapp et al., 2020; Danne et al., 2021; Karasmanaki, 2021; Mamica, 2021).

At the end of the last century, only a few frontrunners were concerned with the possibility of local energy production. An energy self-sufficient house was a precious curiosity in those days. From 2021, houses in the Netherlands may no longer be connected to the natural gas pipeline. In general, it can be said that local sustainable power generation has become a common good with all the possibilities that it offered

that were not available before. Opportunities that ensure people can also take initiative themselves. New technical developments that are becoming more and more economically feasible are electricity storage and demand management. Storage and demand management each individually, but even more so in combination, offer starting points for effective and easy-to-realize behavioral changes (Koirala et al., 2016).

8.2 Regulations

Authors: Frans Coenen, Victoria Daskalova

The energy systems upon which our current industrial society is built have traditionally been centralized, often government-controlled, centrally owned and managed entities. The regulatory framework for energy was designed for this situation. With the liberalization and privatization of energy markets, new actors – privately owned and controlled energy providers – appeared. This led to new market rules and regulatory changes, which, coupled with technological developments, have created opportunities for citizen participation in the energy market. Concerns about climate change have also motivated citizens to take an active role with respect to energy production and consumption.

As we have seen in the new era of energy transition, changes simultaneously occur across a variety of dimensions. The generation is increasingly (aimed to be) decentralized, whereby production (generation) takes place closer to home (on the roof, or in an area nearby), and technologies for production are changing (from burning fossil fuels to harnessing the power of wind and transforming energy from the sun; and increasing use of digital solutions). At the same time, modes of governance are also changing, from command and control to market-based and community-based solutions.

New or adapted regulatory frameworks are needed for a decarbonization of the local energy system. While some of these new frameworks already exist, e.g., in the form of new grid codes for connection of decentralized and renewable production, many are still based on older or existing fossil fuel-based policies. Local energy systems based on these existing or older regulations are not always able to facilitate or encourage the required low-carbon system changes.

When talking about 'regulations' in this section, we mean laws and regulations, including legal permits, planning regulations, energy standards, legally binding covenants, purchase agreements, etc.

8.2.1 Boundaries for the regulatory factor analysis

The history, the energy cultures and energy systems differ across Europe, including across the three SERENE demonstrator sites. This means that there are different challenges and opportunities for low-carbon energy transitions, and different pathways to successful transitions (Vladimirov & Galev, 2017). The aim of this review of regulatory obstacles is to identify general factors. We will not go farther in-depth

on the exact national or local regulations of the demonstrators for three reasons. First, the purpose of this deliverable is not to describe the regulation in force in the three countries, but to identify general obstacles that regulatory factors might pose to the local energy system transition. This analysis does not require exact details of the regulation, but rather focuses on the general link between regulatory factors and energy system changes. Second, current legislation is changing quickly and is often related to the existing local energy systems. Third, there is an overwhelming number of elements of the envisioned new local energy systems related to regulation. Not all of these are of equal importance for our analysis. However, we will only know which factors are relevant after the exact innovations for each demonstrator are selected, meaning that for the moment, we must keep the playing field of regulatory factors open. Additionally, most of the regulations cannot be manipulated or changed by the actors and stakeholders in the demonstrators, and thus might set boundaries and conditions on what can be changed in the local system, unless innovations would be allowed as an experimental practice (exemption or sandbox regulation) (Diestelmeier, 2021; Lammers & Diestelmeier, 2017).

Boundaries for the analysis set by the innovations in the demonstrator sites

We cannot focus on all regulations that would somehow touch the constitution, organization and operation of all building blocks of local energy systems. The most important regulatory factors for this project are factors that relate to the envisioned system changes and specific technical and social innovations. This still includes a wide range of factors, because the innovations ask for new ways to generate, distribute, and consume energy which often do not fit in the existing regulatory system. The regulatory factors we sketch here with relatively broad-brush strokes are to identify the overall conditions for the innovations in the demonstrators. It does not make sense to discuss product standards, distances, citizen, and user involvement regulations in any detail as long as the precise system choices are not yet taken.

As another boundary of our analysis, we prioritize the description of factors that are related to 1) changes in the regulatory framework that can be manipulated by local stakeholders; and 2) regulatory obstacles which might be solved within the time frame of the project.

The local energy system change has to move on even if there are reverse salient parts of the system in the form of regulations. We will therefore limitedly focus on outlining the policy and regulatory changes that need to take place in the coming years to make system changes possible, if these do not lie in the hands of the stakeholders in the local energy system. These are regulatory obstacles that might or might not be solved in the timespan of the project. They form conditions (further elaborated in SERENE project deliverable 3.2) or reasons not to introduce certain technical innovations at this moment of time, or adjust these technical innovations to what is possible. In other words, we cannot introduce these innovations before these regulatory conditions are created. Additionally, even if new policies and policies goals are in place, regulatory frameworks might follow much later. Locally, the wish for technical innovations can induce regulatory changes if they are in the hands of the local stakeholders, or there might be possibilities for exemption or sandbox regulation (Diestelmeier, 2021; Lammers & Diestelmeier, 2017).

8.2.2 Regulation and energy system change

The new local energy system described in Section 3 asks for changes in the operation of the distribution systems, the role of system users connected to the distribution system, and transactions between system users, system operators, and possibly new actors, as well as associated energy market rules. The new system also needs to function within the existing EU energy market.

The energy sector is subject to multiple sources of regulation, which originate at different levels (international and EU, federal/state level, local level). For example, international commitments regarding the reduction of greenhouse gas emissions undertaken by individual countries under the UNFCCC Paris Agreement of 2015 have implications for the choices made about energy markets. These obligations require actions to achieve the promised goals. In addition to regulation from state bodies, additional standards, e.g., technical standards, are elaborated by professional standard-setting bodies such as, for instance, CEN and CENELEC in the EU, and industry groups.

With respect to energy markets, EU legislation is important. The EU has led the process of liberalization of energy markets by introducing common rules for electricity in the common market, by enforcing competition law in energy markets, scrutinizing state aid in the sector, and harmonizing aspects of consumer protection (e.g., regarding supplier choices, billing information and withdrawal periods), the latest of which is the 'Clean energy for all Europeans package' of 2019. Numerous investigations have been led by the Directorate General for Competition of the European Commission. At the same time, national authorities also scrutinize agreements, practices, and unilateral behaviour, as well as mergers in this sector.

Although electricity is not the only part of the local energy system, the regulation of the 'Clean energy for all Europeans package' to make the EU electricity market fit for the clean energy transition is important, as it updated old energy market rules and introduced new ones. Furthermore, this EU package puts consumers at the center of the clean energy transition – the new rules enable the active participation of consumers and create rules for consumer protection. Key documents are the Electricity Directive 2019/944/EU) and three regulations: the Electricity Regulation (2019/943/EU), the Risk-Preparedness Regulation (2019/941/EU) and the EU Agency for the Cooperation of Energy Regulators (ACER) Regulation (2019/942/EU). Additionally, the fourth energy package introduced new electricity market rules to meet the needs of renewable energies and to attract investments. The fifth energy package, 'Delivering the European Green Deal' (14 July 2021), further aims to align the EU's energy targets with the new European climate ambitions for 2030 and 2050 and will lead to further changes. However, in how far the EU regulation is really fitting to low-carbon local energy systems depends on the transposition in national and local regulation (Petrick, Fosse, & Klarwein, 2019).

Grids are an important part of the new local energy system, including, most prominently, the electricity grid, but also biogas, hydrogen and heat grids. Changes in these grids are not just about technological innovation, but need to be accompanied by fitting changes in regulation. New and smarter grids ask us to

revisit regulations related to existing grid services and the participation of grid users, as well as regulation for new grid services. The proposed low-carbon local energy system integrates different energy carriers, creates more suitable local renewable energy production and distributed generation, and demand response resources and energy storage technologies in various energy domains like electricity, heat, water treatment and transport.

Low-carbon energy systems do not only need to abide by energy market and local energy system operation regulation. The use of renewables as the new primary energy sources like solar, wind and biomass and as secondary energy sources (electricity, hydrogen) are all regulated as well. A low-carbon local energy system is not only attained with innovations directly in the energy system, but also with innovations in connected system, many of which are linked to the energy system through energy distribution networks that are connected to energy-consuming devices and activities.

The local level is an appropriate and important level of governance for the energy transition and climate policy. This directly relates to the role of regulatory factors in the local energy system in two ways: (1) local authorities and other stakeholders initiate local activities that result in greenhouse gas emissions, and (2) municipalities have responsibility in many energy-related policy areas. Climate actions by municipalities and local stakeholders can target both the local energy production and distribution systems themselves, and other systems connected to the energy sector. A research project estimated the emissions of greenhouse gases related to activities that fall within the sphere of influence of Dutch local authorities to be more than 40% of the Netherlands' total greenhouse gas emissions (Menkveld, Burger, Kaal, & Coenen, 2001).

In general, the powers of local authorities with respect to energy and climate matters vary greatly from one country to another. History and the resulting administrative organization of each country have determined the relative weight of local power (Coenen & Menkveld, 2002). This affects the general room to operate for municipalities in the energy-related policy fields, which includes the general degree of local autonomy, as well as the specific scope of autonomy with respect to local climate and energy policy, and the local capacity for action in terms of the resources and competencies of local authorities (Lafferty & Eckerberg, 1998). Although there are many differences between countries, local authorities are generally responsible for energy-relevant fields like town and country planning, construction and housing, traffic, environment and local authority management tasks (Coenen & Menkveld, 2002). On the local level, municipalities can influence the local energy transition both directly and indirectly, via target groups. These target groups represent the level of the citizens and communities where decisions are made about the ultimate use of energy, and choices are made about, for instance, transport and the use of renewable energy. Local policymaking is important for realizing a radical change in greenhouse gas emissions, because local policies are important for the key aspects of transition processes that deal with the use of space, the built environment and aspects that rely on household behavior and consumption.

In order to fill their role, local authorities need supportive legislation from higher government levels to bring about the energy transition (Eleftheriadis & Anagnostopoulou, 2015; Emelianoff, 2014). Such

supportive legislation, like national standards, can also serve as a guiding instrument (Burch, 2010) to manage the expectations of local actors, for instance in terms of energy efficiency standards (Eleftheriadis & Anagnostopoulou, 2015), and to provide municipalities with goal orientation and strengthen the legitimacy of local policies (van den Berg, Hoppe, & Coenen, 2014).

8.2.3 General causes for regulatory obstacles

There are four broad scenarios of possible regulatory obstacles for the local energy transition:

1. The main regulatory obstacle is the abovementioned mismatch between what regulation is needed for a new low carbon system and what new regulation is available. Obstacles arise when the existing regulation **does not allow** for the necessary system changes that ask for new ways to generate, distribute and consume energy.

2. The content of the regulation often does not fit with necessary system changes, for instance because regulation is too strict or demanding, and is non-flexible to make required changes **practically possible,** for example because procedures are too time consuming or there is a lack of information about laws and regulations (Williams 2010).

3. Specific new regulation that is needed to make technical and social innovation possible is not available, or there is a time lag in creating this regulation. There might be a mutual stranglehold between technology and regulation. If laws and regulations lag behind technological developments, they inhibit the innovation needed for sustainability, and vice versa. The mismatch between regulation needed for innovation and existing regulation can be called the concept of '**regulatory disconnect**' between regulation and innovation. This might "arise when innovation in the market develops in a faster tempo or differently than envisaged compared to respective regulation" (Butenko, 2016, p. 702). Such disconnects may "in certain cases (….) lead to regulatory failure and should (then) be eliminated" (Butenko, 2016, p. 702).

4. Existing regulation does not allow for new services or new roles in the energy market. Markets are never entirely free, regulations shape the playing field. These market regulations can form an obstacle, for instance due to the **limiting conditions** under which new actors, like an energy community, can operate in the energy market.

Detailed analysis of the regulatory conditions in each demonstrator and for specific interventions is needed to determine whether any of the above scenarios apply, and if so, which one(s).

8.3 Governance

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This section reviews factors that potentially influence local energy system transitions from a governance perspective. It first explains how and why governance is conceptualized as polycentric, as well as the advantages and disadvantages of this conceptualization. It then reviews key features of polycentric governance based on a literature review, which are studied in deliverable 3.2 as potential obstacles or necessary conditions for local energy system transitions.

8.3.1 Polycentric governance

Energy system transitions at any level (from local to international) are often studied as technical systems of solar panels, wind turbines and storage facilities, or as economic business models of investments and revenues. However, this does not explain how energy system transitions come about, as they are also related to power, agency, institutions, legal frameworks, organizations, policies and political ideas, beliefs and motivations (Moss, Beckers, & Naumann, 2015; Young & Brans, 2017, p. 118). These aspects can be combined under the heading of governance.

The concept of governance has undergone a major transformation during the past decades. In the 1990s, the concept of governance was still equivalent to conventional government and intergovernmental cooperation, but by the 2000s, scholars increasingly recognized that governance was no longer exercised only by states, and that subnational and private actors increasingly took the stage (Biermann & Pattberg, 2012; Emelianoff, 2014). This was also the case for energy governance. The traditional provider of energy governance was the government, but as the nature of energy problems became more pressing, new actors such as corporations and members of civil society were put forward to address the gaps in national energy policies (Sovacool & Florini, 2012). Accordingly, this section and deliverable, but also the following deliverables 3.2 and 3.3, are based on the following definition of governance: *any and all processes, actors and institutions involved in steering policies and behavior, and making and enforcing rules, to solve a collective problem and/or ensure the provision of public goods* (adapted from Sovacool & Florini, 2012). This includes processes such as agenda-setting, implementation, monitoring and enforcement of rules; and actors such as governments, non-government organizations, civil society, corporations and citizens (Sovacool & Florini, 2012, p. 237). Moreover, institutions include any form of organization, regime, initiative, partnership or network.

The phenomenon of increased dispersion of processes, actors and institutions involved in (energy) governance has been analyzed and evaluated by scholars in different ways. A widely used the concept, mostly in the context of global (energy) governance, is fragmentation (Dubash & Florini, 2011; Escribano, 2015; Sanderink, 2020; Van de Graaf & Zelli, 2016). This refers to governance systems as a patchwork of institutions that are different in their character (organizations, regimes and implicit norms), constituencies (public and private), spatial scope (from bilateral to global) and subject matter (from specific policy fields to universal concerns) (Biermann, Pattberg, van Asselt, & Zelli, 2009, p. 16). Scholars of energy governance to a lesser extent apply the concept of institutional complexity, sometimes interchangeably with fragmentation (Van de Graaf, 2013). This similarly refers to the crowdedness and increasing interconnections within institutional landscapes (Lane & Robinson, 2009, p. 17). Yet another stream of

research describes energy governance as multi-level (Dobravec, Matak, Sakulin, & Krajačić, 2021; Hermanson, 2018; Jänicke & Quitzow, 2017; Markantoni, 2016). This refers to the notion of *"pluralistic and highly dispersed policy-making activity, where multiple actors (individuals and institutions) participate, at various political levels, from the supranational to the subnational or local"* (Stephenson, 2013, p. 817).

A similar, but distinct concept is polycentric governance. It was put forward by Ostrom, Tiebout, and Warren (1961) and Ostrom (2010a), and is characterized by multiple centers of decision-making at different scales, which each have some degree of autonomy and independent authority to make and enforce rules (McGinnis, 1999; Ostrom 2010a, 2010b; Ostrom et al., 1961). These decision-making units exist at different levels (e.g., local, national, international) and can include units that cut across jurisdictions (Carlisle & Gruby, 2019; McGinnis & Ostrom, 2011). Moreover, these decision-making units include diverse types of organizations drawn from public, private and voluntary sectors (McGinnis & Ostrom, 2011). These characteristics apply to energy governance too. First, processes, actors and institutions exist or emerge at national, European and international levels, while simultaneously the authority of local decision-making on energy is increasing (Dobravec et al., 2021; Emelianoff, 2014; Gancheva, O'Brien, Crook, & Monteiro, 2018). Second, especially with the rise of local energy communities and urban energy initiatives, citizens, energy companies and other private entities increasingly fulfill governance functions as well, influencing decision-making and the implementation, monitoring and enforcement of rules besides public government authorities (see Creamer et al., 2018; Horstink et al., 2020).

Each of these concepts – fragmented, complex, multi-level and polycentric governance – can be used to analyze the intricacy of governance systems and that of energy in particular. However, polycentric governance appears most appropriate and actionable in the context of local energy system transitions. First, since the concepts of fragmentation and complexity are mostly used in the context of global (energy) governance and are focused on horizontal interrelationships between governance arrangements at the same global level (Biermann et al., 2009; Sanderink, 2020; Van de Graaf & Zelli, 2016). Second, because multi-level governance is predominantly used in the context of European governance and policymaking; and while it, compared to fragmentation and complexity, additionally considers vertical interrelationships between governance arrangement at multiple levels, it is applied almost exclusively to public governmental arrangements (Hooghe & Marks, 2003; Jänicke & Quitzow, 2017). Whilst the central argument of polycentric governance is that governance arrangements exist at and cut across different levels including the local level; and simultaneously, polycentric governance focuses on both horizontal and vertical interrelationships between governance arrangements from public to private sectors. Therefore, polycentricity is seen as the most useful to study energy system transitions at the local level, at which both private and public actors play an important role.

Nevertheless, polycentricity has only recently and limitedly been associated with governance of energy system transitions (Bauwens, 2017; Blasch et al., 2021; Goldthau, 2014; Sovacool, 2011) and according to Bauwens (2017, p. 126) *"without significant or systematic development"*. Whilst Goldthau (2014, p. 138)

argues that three elements are likely to exacerbate the need for a polycentric governance approach: first, as national and regional energy policies are more and more informed by a liberal paradigm, the number of involved actors increases as well as the complexity of regulation; second, decarbonizing energy systems calls for more decentralized energy generation; and third, the energy access challenge asks for more tailored and contextualized, and thus, local solutions. In sum, besides the described characteristics of energy governance, also existing trends related to energy systems call for a new approach to energy governance research and polycentricity offers a promising angle. Therefore, this section not only seeks to uncover by which polycentric governance factors local energy system transitions are potentially influenced, it also aims to contribute to significant and systemic development of the polycentric approach to governance of energy system transitions in general.

8.3.2 Theoretical advantages and disadvantages of polycentric governance

In 2009, Elinor Ostrom was awarded the Nobel Prize in economics, which resulted in renewed interest in the notion of polycentricity. With this notion, both Vincent and Elinor Ostrom challenged the need for a monocentric governance system in which there is only one decision-making structure that has the authority to determine and enforce rules. Originally based on a study of a metropolitan region, they argued that some services may be handled more efficiently on a large scale, while others may be better handled on a small scale. Hence, their argument was that there is instead a need for a polycentric governance system in which there is no ultimate decision-making structure and there are multiple authorities with some degree of autonomy to make and enforce rules (Ostrom, 1972; as cited in Aligica & Tarko, 2012). In the years to come, scholars have studied the theoretical advantages and disadvantages of polycentric governance in further detail.

Carlisle and Gruby (2019) have summarized three most commonly cited advantages of polycentric governance. First, polycentric governance systems are assumed to be better able to adapt when faced with change compared to centralized governance (Carlisle & Gruby, 2019). This stems from the idea that if multiple and diverse institutions are involved in governance, they might learn from each other's failures and successes, due to which they may continuously evolve into more effective institutions (Ostrom, 1999). In addition, it is based on the assumption that in polycentric governance systems, there is more room for experimentation with rules and behavior, leading to institutional innovation (e.g., Ostrom, 1999; Pahl-Wostl, Lebel, Knieper, & Nikitina, 2012). Second, polycentric governance systems are claimed to provide a good fit between the institutions involved and the problem that needs to be addressed, especially when it comes to natural resource systems (Carlisle & Gruby, 2019; Lebel et al., 2006). A good fit implies that institutions are designed in such a manner that they can efficiently and effectively accomplish certain goals. Most resource systems, including energy, are complex and consist of subsystems at different levels. As multiple and diverse institutions are involved in polycentric governance systems, these systems are assumed to provide these institutions for different subsystems at varying levels (e.g., Carlisle & Gruby, 2019; Ostrom, 2007). In addition, the fact that a mix of state and non-state actors are involved, results in knowledge that is complementary and presumably informs more contextually adapted institutions, thereby enhancing institutional fit (Carlisle & Gruby, 2019; Cash et al., 2006). Third, polycentric

governance systems are argued to reduce the risk of institutional failure through redundancy (Carlisle & Gruby, 2019; Ostrom, 1999). Redundancy here refers to the multiple and diverse institutions that are engaged in governance. These institutions can be largely complementary, but more importantly, this also implies that if one institution fails in its governance activities, the others may provide more effective alternatives, mitigating the overall failure to address the problem or need at hand (Carlisle & Gruby, 2019; Low, Ostrom, Simon, & Wilson, 2003). Generally, polycentric governance systems are argued to *"enhance innovation, learning, adaptation, trustworthiness, levels of cooperation of participants, and the achievement of more effective, equitable, and sustainable outcomes at multiple scales"* (Toonen, 2010, as cited in Ostrom, 2010a, p. 552).

Simultaneously, it is important to critically study the disadvantages of polycentric governance systems, as they do not necessarily perform well or better than other governance systems (Marshall, 2015; Ostrom et al., 1961). Several scholars have studied the limitations and challenges to applying a polycentric approach. First, the downside of the previously mentioned redundancy of institutions in polycentric governance system is the danger of inefficiency and high costs associated with coordination (Carlisle & Gruby, 2019; Huitema et al., 2009; Wyborn, 2015). Such coordination may be necessary to prevent duplication of efforts or counterproductive action by governance institutions. Moreover, as Dorsch and Flachsland (2017) argue in the context of climate mitigation, it is difficult to aggregate and measure such costs and weigh them against the benefits of polycentric efforts. Second, scholars have argued that issues may arise to hold governance institutions accountable for their performance due to the dispersion of responsibilities (Carlisle & Gruby, 2019; Huitema et al., 2009; Lieberman, 2011). This may not apply to traditional governmental and civil society institutions, whose practices are based on transparency and democratic principles. However, other and newer types of collaborative institutions of public and private actors may prioritize goal achievement over democratic procedures (Huitema et al., 2009; Skelcher, 2004). Accountability mechanisms to hold such institutions accountable for their performance may not be available, let alone a common standard to which their performance should be measured. Finally and related to this, the risk of free-riding in a polycentric governance system continues to exist. Dorsch and Flachsland (2017, p. 58) have found this in the global governance system for climate mitigation: compartmentalizing the challenge and dispersing the responsibilities of governance institutions accordingly *"opens up corridors to 'exploit' the willingness of a diversity of actors to contribute,"* but simultaneously, *"site-specific free-riding incentives, leakage effects, and the persistent resistance of opposing actors are likely to prevail."*

8.3.3 Polycentric governance factors

Scholars have studied the advantages and disadvantages of polycentric governance quite extensively, however, there is comparatively little study on the governance features (or: characteristics) that yield such advantages or disadvantages (Carlisle & Gruby, 2019; Jordan, Huitema, Schoenefeld, van Asselt, & Forster, 2018). Accordingly, Carlisle and Gruby (2019, p. 947) have argued that it is critical to investigate *"where, and under what circumstances, polycentricity in governance can lead to expected or desired outcomes."* However, there is no commonly agreed overview of the basic features of polycentric

governance in the first place. Some scholars describe the more structural characteristics of polycentric governance that can readily be observed, for example that polycentric governance systems consist of multiple decision-making authorities which self-organize according to a set of overarching rules (e.g., Aligica & Tarko, 2012; Carlisle & Gruby, 2019), whereas others study the more substantive features that require an in-depth look at governance systems, such as the emphasis on experimentation and local action or the existence of trust and accountability mechanisms (e.g., Dorsch & Flachsland, 2017; Jordan et al., 2018). This section reviews and summarizes eight key polycentric governance features that may influence local energy system transitions as factors.

The first key feature of polycentric governance on which there is general agreement, is that a polycentric governance system consists of multiple, overlapping decision-making centers with some degree of autonomy (Carlisle & Gruby, 2019, p. 932). It is thereby important that these decision-making centers are not restricted to formal governmental bodies; according to McGinnis and Ostrom (2011, p. 15), *"private corporations, voluntary associations, and community-based organizations play a critical supporting roles in polycentric system of governance, even if they have not been assigned public roles in an official manner"*. Moreover, decision-making centers should not be considered in a very strict sense. Besides public bodies that have *"considerable independence to make norms and rules"* (Ostrom, 1999, p. 552), communities who make and enforce unwritten norms and rules are candidates for a decision-making center status (Carlisle & Gruby, 2019). Additionally, institutions and actors with no authority to make rules, but with a strong influence on policies for instance by providing technical or financial support, play a critical role in polycentric governance systems as well (Carlisle & Gruby, 2019; McGinnis & Ostrom, 2011). Consequently, decision-making centers are rather institutions and actors with a significant governance function, be it formal rule-making, informal standard-setting or providing informational and financial support. These institutions and actors can overlap in the way that they may operate at similar levels (e.g., local, national, international) and cut across levels (McGinnis & Ostrom, 2011). Finally, it is inherent to polycentric governance that these institutions and actors have "some degree" of autonomy or independence to influence, make or enforce rules, which according to Carlisle and Gruby (2019) indicates that the degree of autonomy necessary to benefit from polycentric governance is yet an open question. In sum, the first polycentric governance feature and potential factor to influence local energy system transitions can be described as **the extent to which multiple and diverse overlapping institutions and actors at multiple levels that have some degree of autonomy to influence, make and enforce rules in the governance system.**

The second feature of polycentric governance system has been referred to by scholars as self-organization (Carlisle & Gruby, 2019), mutual adjustment (Jordan et al., 2018), self-correction (Aligica & Tarko, 2012) or spontaneity (Polanyi, 1951). Generally, this refers to the idea that "*patterns of organization within a polycentric system will be self-generating or self-organizing"* in the sense that *"individuals acting at all levels will have the incentives to create or institute appropriate patterns of ordered relationships"* (Ostrom, 1972, as cited in Aligica & Tarko, 2012). While this claim comes across as rather positive, Ostrom et al. (1961) explains that these ordered relationships come about – more specifically – through processes of

cooperation, but also competition, conflict and conflict resolution. Cooperation refers broadly to voluntary joint action that is inclusive of processes such as collaboration and contractual undertakings (Ostrom et al., 1961). With competition, Ostrom originally referred to municipalities that were forced to compete for residents through their mix of public goods and services on offer (Ostrom et al., 1961), but more broadly, this can refer to competition between governance institutions for the right to lead or influence initiatives of political steering or competition of ideas and methods (Carlisle & Gruby, 2019). Even conflicts can result in ordered relationships, provided that they do not escalate; specifically, conflicts can result in change and learning when different interests and perspectives are being raised in the process of conflict resolution (Dietz, Ostrom, & Stern, 2003). Thus, capability to resolve conflict is critical. In more practical terms, self-organization also implies that there is freedom for newly established institutions and actors to enter and exit the polycentric governance systems (Aligica & Tarko, 2012). For instance, new institutions and actors may step in when existing ones are not able to meet the objectives of a governance system (Carlisle & Gruby, 2019). In sum, self-organization is manifested in the possibility to reform and revise the polycentric order. Based on the foregoing, the second polycentric governance feature and potential factor to influence local energy system transitions is described as **the degree to which there are tendencies of self-organizing that result in patterns of ordered relationships between institutions and actors in the governance system.**

Almost all descriptions of polycentric governance systems refer to the third important feature of polycentric governance systems: the existence of a set of overarching rules (e.g., Aligica & Tarko, 2012; Carlisle & Gruby, 2019; Jordan et al., 2018). It partly links to the previously described feature; Aligica and Tarko (2012, p. 246) argue that one of the conditions for a self-organizing polycentric governance system is that there are general rules of conduct that provide a legal framework for a polycentric order. Carlisle and Gruby (2019, p. 937) extend this claim and stress the importance of generally applicable rules and norms structuring actions and behaviors. The idea is that such overarching rules and norms provide boundaries to existing and new governance activities, and at the same time, sufficient room for experiments and creative solutions. More concretely, this implies that overarching rules and norms are necessary to ensure that overall objectives of the governance system are achieved and that conflicts across institutions and actors are resolved, thus supporting the self-organization of the governance system (Jordan et al., 2018). While this feature is broadly agreed upon, there is no consensus on the form and function of overarching rules and norms (Jordan et al., 2018). The question unanswered in literature is whether this refers to formal rules of state organizations – e.g. courts to resolve disputes or agencies that monitor progress, or whether this also includes informal societal norms and values (Ibid.). Jordan et al. (2018) argue that the first interpretation is counterintuitive as it is rather associated with monocentricity, more so than polycentricity. Therefore, it is assumed here that the second interpretation is more compatible with the two features of multiplicity of institutions and actors, and the self-organizing patterns of relationships. Accordingly, the third polycentric governance feature and potential factor to influence local energy system transitions can be described as **the presence or absence of overarching formal and informal rules and norms that ensure aligned objectives and conflict resolution in the governance system.**

The fourth feature is that there should be effective mechanisms for accountability present in polycentric governance systems (e.g., Carlisle & Gruby, 2019; Sovacool, 2011). Accountability refers to the notion that actors can hold institutions or other actors accountable, to judge whether their responsibilities have been fulfilled in light of certain standards, and to impose sanctions if this is not the case (Keohane & Nye Jr., 2003). Traditional mechanisms for accountability are electoral processes, deliberative processes, public hearings or demonstrations (Skelcher, 2004), but these are not adequate in polycentric governance systems in which the authority to make, enforce and influence rules is dispersed among both public and private institutions and actors (Carlisle & Gruby, 2019). In fact, some scholars argue that accountability is challenged by polycentricity due to the high number of institutions and actors, and especially the lack of clarity about the relationships between these (e.g., Blomquist & Schlager, 2005; Lieberman, 2011). Other scholars, on the contrary, argue that polycentric governance systems consist of more effective accountability mechanisms. Precisely because of the fact that governance occurs at multiple levels, due to which there are more opportunities for institutions, actors as well as individuals to correct for unfair distribution or abuse of authority (Ostrom, 2000, as cited in Carlisle & Gruby, 2019). Literature on polycentric governance does not yet provide examples of alternative accountability mechanisms, but Carlisle and Gruby (2019) draw on possibilities for decentralized governance arrangements, such as monitoring by independent third parties (e.g., media or NGOs), auditing and evaluation, public report requirements for governmental decision-makers, education, performance awards and oversight by higher levels of government (Agrawal & Ribot, 1999). Based on this, the fourth polycentric governance feature and potential factor to influence local energy system transitions is here described as **the (non-)existence of a broad range of both conventional and unconventional mechanisms for accountability.**

The fifth feature is the argument that local actions play a key role in polycentric governance systems (Dorsch & Flachsland, 2017; Jordan et al., 2018; Ostrom, 2009). This is based on the assumption that actions at the local level accumulate and therewith contribute to collective problem-solving. Ostrom (2009, p. 15) clearly explains this in the context of climate change: *"Part of the problem is that 'the problem' has been framed so often as a global issue that local politicians and citizens sometimes cannot see that here are things that can be done at a local level that are important steps in the right direction" (See also Betsill, 2001)*. This appears to be a response to the fact that scholars and practitioners were too focused on realizing collective action at the international level, while this could also be addressed at smaller scales and many levels at the same time (Ostrom, 2009, as cited in Jordan et al., 2018). This demonstrates that it is, however, important to note that it is not meant to exclude other levels of action, such as the regional or national. The primary argument, related to the principle of subsidiarity, is that problems are best dealt with at the level most closely related to the problem (Dorsch & Flachsland, 2017, p. 51), which is often the local level. Based on the foregoing, the fifth polycentric governance feature and potential factor to influence local energy system transitions is here described as **whether a key role is assigned to local actions that accumulatively contribute to collective action.**

The sixth feature of polycentric governance systems is the recognition of site-specific conditions, thus taking into account specific actors and situational characteristics (Dorsch & Flachsland, 2017). Similar to

the previous feature, it builds on the idea that understanding and recognizing the specific capabilities of actors and situational characteristics of a certain level – e.g., local or regional, instead of aggregating and generalizing these, will enhance progress towards the overall goal. According to Dorsch and Flachsland (2017, p. 53), this can be further specified in three tasks. First, understanding and recognizing the heterogeneous preferences of institutions and actors, thus asking "who wants to do what?" In the context of climate change, the authors argue that tailoring policies to site-specific preferences can avoid inefficiencies of uniform regulations applied at broader levels. Second, understanding and recognizing their heterogeneous competencies and constraints by asking "who can do what?" The assumption here is that it is important that policies are adapted to competencies and constraints, which are bound by political arenas, economic situations and societal contexts. Third and finally, understanding and recognizing the interactions between these preferences, competencies and constraints. Following Dorsch and Flachsland (2017), the sixth polycentric governance feature and potential factor to influence local energy system transitions is here described as **the recognition or ignorance of site-specific conditions, including preferences, competencies and constraints of institutions and actors and their interactions.**

The seventh feature of polycentric governance systems is the emphasis on decentralized experimentation and mutual learning (Dorsch & Flachsland, 2017; Jordan et al., 2018; Ostrom, 2010a). According to Dorsch and Flachsland (2017, p. 55), experimentation and mutual learning is necessary for improving and reducing the costs of governance over time. This in turn is argued to foster innovation, flexible adaptation, and the production and diffusion of new knowledge. The argument is that experimentation with institutions may have more impact in a top-down monocentric governance system, but in a polycentric governance system such experiments will have impact at multiple levels and scales (Dorsch & Flachsland, 2017). In other words, the successes and failures of such experiments are expected to create a spillover effect in the overall governance system (Ibid.). For instance, in the case of climate change, a polycentric approach is therefore argued to increase the benefit of these interconnected innovation processes, compared to a more monocentric approach. In sum, the seventh polycentric governance feature and potential factor to influence local energy system transitions is here defined as **the (lack of) emphasis on experimentation and learning at different levels of governance, fostering innovation processes that are spilled over in the overall governance system.**

The eighth and final feature is the strong emphasis in polycentric governance systems on trust and accompanying mechanisms to build and enhance trust (Dorsch & Flachsland, 2017). Trust is important for effective cooperation across institutions and actors, and the argument is that it is enhanced in polycentric governance systems compared to more monocentric approaches. Dorsch and Flachsland (2017, p. 57) illustrate this in the case of climate change: instead of abstracting away individual relations as in traditional approaches of governance, where internally homogeneous nation-states or aggregated societal interest groups are the relevant actors to look at, a polycentric approach emphasizes trust as a product of face-to-face communication and as a means to enhance cooperation. Ostrom (1990) provided concrete examples of mechanisms to build trust – face-to-face communication, monitoring and graduated sanctioning – and describes these as trust catalysts which exist across scales and levels (cited in Dorsch &

Flachsland, 2017). Consequently, the eighth polycentric governance feature and potential factor to influence local energy system transitions is here defined as **the presence or absence of trust and mechanisms to enhance trust across scales and levels.**

This section reviewed and summarized eight polycentric governance features and factors that potentially influence local energy system transitions. Deliverable 3.2 reflects on the extent to which these factors may result in potential obstacles and necessary conditions for local energy system transitions. This is done by relating the identified polycentric governance features and potential factors to existing literature on local energy system transitions. This body of literature includes articles and chapters that study the manifestation of local energy system transitions in many varying ways, from "urban energy transitions" and "renewable energy cooperatives", to "local energy planning" and "grassroot initiatives". Though what it comes down to is that the literature can broadly be divided in two streams: one focusing on community energy (e.g., Brummer, 2018; Creamer et al., 2018; van der Schoor, van Lente, Scholtens, & Peine, 2016) and one studying energy transitions in cities (e.g., Hawkey, Webb, & Winskel, 2013; Hoppe & Van Bueren, 2015; Lee, 2017; Ruggiero, Busch, Hansen, Isakovic, 2021). Regardless of how local energy system transition manifests itself, all of this is based on the central assumption that it occurs in governance systems that can be characterized as polycentric.

8.4 Urban planning

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This section focuses on urban planning factors that influence local energy system transitions. It first reviews the literature on energy planning in relation to spatial equilibrium logic, and then focuses on multi-sectoral/multi-objective considerations and bottom-up urbanism.

8.4.1 Energy planning and the spatial equilibrium logic

In free market economies, especially as one zooms into finer geographical scales, household behaviors such as mobility, freedom of choice, and relocation capabilities, constantly confront urban planning with one of the main implications of the spatial equilibrium: if something good happens in a neighborhood due to market forces or planned interventions, one should expect negative things offsetting it (Glaeser 2007; Brooks, 2012). For instance, energy efficiency improvements will raise residential real estate prices (Fuerst et al. 2015), decreasing housing affordability, and setting off relocations of households that cannot afford the new price levels. In the terms of Brooks (2012), households can vote with their feet. Similarly, increases in the attractiveness or success of urban districts will typically be accompanied by a series of negative externalities (connected for instance to land use changes, affordability, segregation, and environmental quality) which will affect the sustainability profile and resilience of the local social and technical systems. Moreover, since cities are not closed systems, the offset mechanism might be subdued at one location, but cannot be contained due to spill-over effects. In practice, for comprehensive urban planning, these notions refer to the fact that the geographical patterns of resource allocation (for

instance, housing, ecosystem services, transport infrastructure, commerce, industry, and heating infrastructure) have a structural relationship with the socioeconomic development and well-functioning of a place at multiple scales, from the neighborhood to the regional level. It has been shown that cities and territories are spatially optimized systems. Spatial optimization—or spatial equilibrium—does not necessarily imply efficiency and equity (that is, a 'best' outcome), but rather means that a relational structure exists between people's behavior and the various parts of a city, which in turn also affects the human and physical capital present in a city (Brooks, 2012). Since space is scarce and there are multiple contestants for its use allocation, the relational structure means that choices about energy systems—for instance, source, distribution, locational configuration, pricing—affect and are affected by choices about other important resources—for instance, through zoning, land use planning, and related place-based regulation, taxation, incentives, restrictions—with, again, both affecting eventual human capital and sustainability of a place.

This interdependence is increasing considerably with localized sustainable energy production and its matching to local demand, the democratization of the energy distribution infrastructure, and the notion of self-sufficient local energy communities that moreover form interacting networks within and across each other. Ultimately, the distributed and decentralized nature of local energy communities means that energy systems are becoming so intertwined with the other aspects of spatial planning, that they constrain but also optimize each other. Spatial planners and economists have been typically dealing with such issues from a top-down perspective; for instance, Brooks (2012) is concerned with how planners and economists can steer urban well-being, while Blair (1995) is concerned with optimizing local economic structure. This perspective has a strong utilization in climate change mitigation at the urban scale; for instance, Seto et al. (2014) provides a systematic overview of how decisions concerning land use, density, transport, and mobility interact to produce more or less favorable emission profiles.

8.4.2 Multi-sectoral/multi-objective considerations

The aforementioned trends have found their way in the notion of Positive Energy Districts (PEDs) as one of the most recent comprehensive attempts in integrated energy and urban planning. A PED is a community design concept that starts from typical sustainable energy objectives such as efficiency, self-sufficiency, and local renewable energy production (Shnapp, Paci, & Bertoldi, 2020). However, the concept is guided by a number of guiding principles that have the purpose to integrate energy supply and demand into the wider flows, activities and livability of the neighborhood: energy efficiency, flexibility, and production optimization must be integrated with quality of life, inclusiveness, and sustainability (Bossi, Gollner, & Theierling, 2020; Gollner et al., 2020). Cf. Seto et al. (2014), which traces similar spatial planning concepts from the perspective of GHG emissions. Ultimately, for this integrative concept to work, several enabling factors are reported: (1) political vision and governance framework; (2) active involvement of problem owners and citizens; (3) integration of energy and urban planning; and (4) ICT and data management (Gollner et al., 2020).

Debizet, Tabourdeau, Gauthier, and Menanteau (2016) take a vertical perspective and provide a way to map the PED enablers to a multiscale system called socio-energetic nodes. The concept proposes a socio-technical systems conceptualization of the multiple public and private actors involved in the generation, distribution, and use of energy, with a mapping of those into three concurrent systems: the infrastructure used at the regional, city, neighborhood, city block, and building scale; the corresponding ownership structures; and the relevant synergies or separations between the types of energy involved.

Complementary to Debizet et al. (2016), Petrescu, Petcou, and Baibarac (2016) take a horizontal perspective and conceptualize how the neighborhood's local renewable energy sources (RES) can be integrated into its other material and immaterial resource flows from a public goods and community governance perspective. In particular, Petrescu et al. (2016) integrate RES into a neighborhood's urban gardening, food production flows, recycling flows, local shops, and a host of immaterial flows such as community centers, educational centers, and libraries. The experiment showed improvements in several of the PED notion's guiding principles, with the main ones being improvement in key performance indicators related to economic benefits, climate resilience, and social capital. The main enabler for the success was the realization of those resource flows as common goods and their concurrent collective governance and management, as well as common distribution of benefits in an otherwise vulnerable community that was ridden by multiple social and economic problems.

Unfortunately, the main obstacle for its continuation through time was the local government and its views on public resources (e.g., land use, property rights), which made the point that integrated energy and urban planning needs the commitment and participation of the host municipality, while at the same time clarifying the structures of ownership rights. In this respect, Busch, Roelich, Bale, and Knoeri (2017) used an agent-based modelling approach to understand the factors that may lead to the upscaling of local energy infrastructure (in their case, heat networks). They concluded that it is crucial to consider the motivations and capabilities of three types of actors – municipal, commercial, and the community – with the policy portfolio designed specifically to adapt to these heterogeneous motivations and capabilities through time. Local authorities and community groups are especially driven by the creation of social value, with techno-economic and emission criteria being less important. Furthermore, they note that enabling learning, having local authorities onboard, and following through the individual stages of the decision process are key success factors (Busch et al., 2017).

All in all, both Petrescu et al. (2016) and Busch et al. (2017) open up an important departure of integrated energy and urban planning, from top-down paradigms to the notion of adaptive, bottom-up urbanism where the participation of the local authorities is still crucial but assumes a more equal role alongside local communities and businesses.

8.4.3 Bottom-up urbanism

However, in recent years such approaches have been complemented (or sometimes overshadowed) by the notion of bottom-up urbanism: the idea that, if we are to hope for sustainable and resilient cities,

citizens ought to be in the driver's seat of their own lived environment. Smart cities are to be co-created (See van der Graaf, Nguyen Long, and Veeckman, 2021). At a more fundamental level, the conceptualization of the city—in our case, its resources—has moved away from a narrow notion of public or private goods, as neither has the private sector the incentive to provide the necessary level, quality, and pricing of fundamental goods such as energy, nor can the public sector always determine the right provision parameters and interventions (Gruber, 2005). In their place, the notion of common goods has been taking a strong footing: goods that are seen as non-excludable, have inherent rivalry (Gruber, 2005), and can nevertheless steer cities into resilient pathways (Shareable, 2018). At the same time, the literature in climate change adaptation and climate resilience has been reinforcing the idea that sustainable local configurations are fundamental to minimize climate change risks but have to be realized by operating on a number of participatory, inclusive, and inherently community-based concepts (Seto et al., 2012).

Deliverable 3.2 approaches obstacles and enabling factors regarding the proliferation of local energy communities from those standpoints, recognizing that while some obstacles or factors can be found inside the energy domain, many are found in integrated community planning.

8.5 Social acceptance

Author: Dasom Lee

This section focuses on social acceptance factors that influence local energy system transitions. It discusses individual, technological and structural aspects of energy transitions, and public perception and social acceptance. In the context of local energy system transitions, this concerns the acceptance of two main components: energy transitions and energy decentralization.

8.5.1 Social, public, and technological acceptance

Acceptance is generally discussed in social and environmental psychology, because it refers to behavioral responses that either favor or oppose certain political or economic transformations (Emmerich et al., 2020). However, there is some confusion between "acceptance" and "attitude," as they are often used interchangeably (Huijts, Molin, & Steg, 2012). The goal of this section is not to define the concept of acceptance. Instead, it focuses on how the public perceives and reacts to technological and structural changes that are currently happening in the energy industry. Therefore, the concept "acceptance" is used in the broadest sense: it discusses people's perceptions, attitudes, and thoughts towards a social transformation of energy, and the processes of public involvement and people's reactions.

The understanding of acceptance, for this deliverable, has three components: social, public, and technological. Social and public acceptance are used interchangeably because they are referring to the level of tolerance towards social aspects of energy transitions, such as equity, democracy, and

sustainability among the public. In other words, *social acceptance* refers to the themes that would require acceptance and *public acceptance* refers to the target group, including both consumers and prosumers (Wolsink, 2018). This is based on the understanding that social acceptance towards energy transitions tends to be more structure- and path-dependent rather than agency-dependent (Seidl et al. 2019). Therefore, the focus should be on the structural variations that lead to energy transitions rather than individual status and agency. Following from this understanding, the next section of this deliverable focuses on opportunity structures, which stresses the importance of structural preferences and opportunities for change.

Technological acceptance is somewhat different from social acceptance because they bring up sensitive personal issues such as health, privacy, and security. This is particularly the case in relation to smart meters, which is the base technology for the energy digitalization transition. The development of new energy technologies is considered as a significant effort to restructure the energy industry, a move way from centralized energy powerhouses to greater public participation and decentralization (Hess, 2018; Lee, Hess, & Neema, 2020; Loiter & Norberg-Bohm, 1999). However, due to a number of uncertainties and concerns, there have been movements against technological transitions towards smart energy (Lee and Hess 2021; Hess and Colely 2014).

8.5.2 Opportunity structures

There are preferences that are caused by structural changes or opportunities. In this section of the report, we discuss how opportunity structures affect public perception and acceptance.

Political opportunity structures

The concept of opportunity structures was introduced by Peter Eisinger (1973) in an attempt to explain the environmental variables that create an opening for protests to occur. He drew a hypothesis that became the foundational understanding of opportunity structures: protests occur in a political system that has both repressive and responsive characteristics. In other words, protests are less likely to occur in an environment that is completely closed off or extremely open. He argued that cities with protests tend to have the structure of political opportunities that are not open to its fullest but still allowed access to and formal representation in government. Here, Eisinger (1973) specifically discussed the openness and the responsiveness of the political systems.

However, the concept of political opportunity structure further developed and started to incorporate other environmental factors that lead to the likelihood of protests. Tilly (1978) expands Eisinger's understanding of political opportunities by incorporating elements of temporal and spatial changes of opportunities. Similar to Eisinger, Tilly (1978) claims that there is a curvilinear relationship between the frequency of protest and political openness. Further building on this framework, Kitschelt (1986) claims that "political opportunity structures are comprised of specific configurations of resources, institutional arrangements and historical precedents for social mobilization, which facilitate the development of

protest movements in some instances and constrain them in others" (p. 58). Building onto Eisinger's ideas on political systems that define political opportunity structures, Kitschelt (1986) claims that in addition to openness and closedness of opportunity structures, we need to focus on the "output phase of the policy cycle [that] shapes social movements and offers them points of access and inclusion in policy making" (pp. 62-63). In this sense, he is broadening the definition of the political opportunity structures by including the number of political parties, fractions, and groups, capacity of legislatures to develop and control politics, patterns of intermediation between interest groups, and the ways in which new demands are incorporated into the process of policy compromises and consensus into the equation.

Scholars and analysts of political opportunity structures have used the following variables to theorize and measure the concept: the degree of institutional accessibility such as strong and weak states (Koopmans and Kriesi, 1995; Krasner, 1977) and the accessibility of the political system (Costain, 1992; Eisinger, 1973; Tarrow, 1989; Tilly, 1978), policy cycle and points of inclusion in policy making (Kitschelt, 1986; McAdam, 2010), alliance structures (Kitschelt, 1986), and prevailing strategies of social movements (Kitschelt, 1986). Undoubtedly, not all of them agree that all these variables should be used to define and interpret the concept of political opportunity structures nor do they agree that these are the only dimensions.

On the other hand, a group of scholars cautiously reject the usefulness of political opportunity structures and its ability to accurately measure the emergence and the success of a movement. Goodwin, Jasper, and Khattra (1999) argue that because the theory tries to incorporate nonstructural factors into the structural model, there is little recognition for the influence of nonstructural elements – i.e., the factors that are within the control of movement actors. By doing this, they are stretching out the concept and thereby making the concept unfalsifiable (Goodwin et al., 1999).

This criticism was addressed in Koopmans (1999) article in which he argues that there are varying definitions, levels, and forms of political opportunities. This, he interprets, is actually a strength of the model because it allows us to evaluate and analyze movements in a context-specific way. However, Koopmans acknowledge that the model is "guilty of structural imperialism, political imperialism, or a combination of both" (1999, p. 95) and that political opportunity structure alone can never fully explain the development of most social movements. Koopmans argues that no student of political opportunity makes the claim that it is the universal and invariant model, and that Goodwin and his colleagues' (1999) arguments are superfluous.

Industry opportunity structures

Industry opportunity structures is a concept that derives from the discussions of political opportunity structures. Scholars of industry opportunity structures attempted to apply the concept to explain the emergence, development, and the impact of social movements that are directed towards corporations instead of the state. Although corporations do have some similar characteristics to the government, such as their ability to impact the market, consumer behavior, and social and political environment of a community, they are inherently different on three different accounts. First, corporations do not have the

policy-making power that the state does. This is important because the government uses policies to change the landscape of the market, while corporations tend to use the supply and demand curve while adhering (most of the time) to the policies introduced by the government. Second, a chairman or a president of a company tend to have more power over their corporation compared to the president over their country. Although it greatly varies from company to company, CEOs of a company with a significant amount of market share tend to exercise more control over their corporation. Third, corporations tend to focus on a smaller dimension of social, political, and economic environment than the state. In other words, most corporations tend to focus on the social and political matters that impact their industries directly and the market position of their companies and their competitors, rather than the entire and the political climate of the country as a whole. This is an important distinction, because this allows corporations to narrow down their interests and relevant parties and institutions and consequently, the nature of the social movement targeting corporations is different from the social movements that target the state.

Raeburn (2004) argues that corporate windows of opportunity open with organizational opportunities. These organizational opportunities are largely divided into three different types: structural template, organizational realignments, and allies. Structural template is often considered as a successful outcome of a movement, and it can also be seen as a form of intuitional opportunity. For example, if an ethnic or racial minority or female employee had won this institutional form of access, it would be a good example as to how a social movement can change the corporate structure, which symbolizes a favorable policy outcome as well as an important mobilization outcome. Raeburn gives three examples of structural template: mechanisms for official corporate recognition, access to institutional resources, and representation on a diversity council. All three represent a successful corporate recognition in which marginalized employees receive official recognition of their work, successful career, and possible discrimination that may have been the target of a movement.

The concept of organizational realignments is particularly interesting and relevant to the discussions in this deliverable. Raeburn writes “when the focus of contention is the corporation rather than the state, the appropriate counterpart to electoral shifts is organizational realignments” (Raeburn, 2004, p. 165) which consequently lead to organizational opportunities. She gives the following as the examples of organizational realignments: elite turnover, shifts in the balance of the board, and mergers and acquisitions. Social movements may not always have the power to change CEOs, demographic and political changes of the board of directors, or mergers and acquisitions. These are often internal corporate decisions that outsiders have a little say in. However, when these internal changes happen, social movements can seize the opportunity and seek a corporate change that they have been yearning for. Raeburn specifically discusses the importance of having a new CEO for what she calls the GLUE (Gay and Lesbian United Employees) movement.

Raeburn (2004) also argues that allies such as “influential individuals, groups from within or close to the elite, or other organizational challengers who serve as coalition partners” (2004: 171) can serve as organizational opportunity. In this sense, Raeburn perceives organizational opportunities as corporate dimensions that have been created by the movement (structural template, allies), already existing

conditions (organizational realignments, allies), as well as the outcome of a social movement (structural template).

Schurman (2004) provides another perspective on industry opportunity structures, focusing on "the corporate industrial spheres in order to theorize how industry structures and cultures shape the environment that social movements face" (p. 247). From this, it is evident that Schurman perceives social movements as being affected by already existing institutional structures rather than social movements having the power to create or close down an opportunity structure. This understanding is also different from Raeburn's (2004) arguments who perceived structural templates as the possible outcome of a social movement.

Opportunity structures in the energy transition

More recent studies use the concept of opportunity structures not just to describe the likelihood of protests and social movements, but also social transitions and changes. In particular, opportunity structures have been extensively used in energy transition studies (Hess & Lee, 2020; Lee & Hess, 2019; Leiren, Inderberg, & Rayner, 2021; Lewallen, 2018; Princen & Kerremans, 2008; Schweitzer & Mix, 2021) and innovation studies (Borrás & Edler, 2014; Elzen, Geels, Leeuwis, & Van Mierlo, 2011; Schurman, 2004). These studies attempt to explain the existing regimes and conditions that are more or less likely result in societal or technological changes. The opportunity structures framework has been one of the growing theoretical overviews in many energy journals such as *Energy Research & Social Science* (ERSS) and E*nvironmental Innovation and Societal Transitions* (EIST).

Understanding opportunity structures has been particularly important in predicting organizational, institutional, and individual behaviors in relation to energy transitions. For example, Lee and Hess (2019) showed that temporal and spatial characteristics have a profound impact on the framing of solar energy transitions. Similarly, Schweitzer and Mix (2021) showed that political opportunity structures in France have been one of the core components in the development of the country's civil nuclear program.

8.6 Societal debates

Authors: Florian Helfrich (5.6.1), Ewert Aukes (5.6.2)

This section focuses on societal debates as factors influencing local energy system transitions. It first introduces the changing role of society and individual citizens in the local energy transition and the new local energy systems we envision in SERENE. Building further on the notion of active energy citizenship, it then reviews the role of discourses and socio-technical imaginaries, as well as their materialization in society.

8.6.1 The new role of citizens in local energy communities

Stakeholder networks in local energy communities

Various stakeholders on energy markets are connected and affected by the development and operation of peer-to-peer energy infrastructures in local energy communities. Through the creation of novel infrastructures that influence the ways in which energy is produced, distributed and shared locally, new forms of interaction and relationships between energy market stakeholders arise. Instead of a very unidirectional setup for energy infrastructures and markets, in which citizens have a passive role as consumers, the proposed infrastructures in local energy communities provide the possibility for local energy production and peer-to-peer trading of energy (Li, Bahramirad et al. 2019; Mengelkamp et al. 2018). In such multidirectional set-ups, citizens and other stakeholders have the possibility to produce energy themselves locally, for instance through solar panels on their roof, and share or trade it with others. Instead of conventional structures with a centralised approach to power supply and distribution, these novel energy infrastructures are decentralised (Mengelkamp et al. 2018; Zhang, Wu, Zhou, Cheng, & Long, 2018).

Along the development of new forms of energy production and distribution, it appears that new forms of interaction with regards to these infrastructures emerge. Stakeholders in the context of local energy communities appear to have new forms of interaction between them, as well as novel forms of agency in the energy sector and its markets (Zhang et al. 2018). Therefore, the societal context of local energy communities constitutes a research object in which the various dynamics and relationships between stakeholders, their interactions with technical aspects of the infrastructure and a wide array of individual perspectives and motivations become intertwined and mutually co-producing. The analysis of the relationships, practices and arrangements of stakeholders within this context of the energy sector constitutes an essential aspect in this research.

The implementation of infrastructures for local energy sharing and trading in the energy sector, especially in the context of local energy communities, might create novel stakeholder arrangements, societal practices and forms of governance. Through disintermediated and decentralised energy structures, local communities have the potential to develop forms of self-sufficiency for the ways in which energy is produced, shared and managed in their community. Such so called “citizen utilities” or “energy citizens”, profit from additional forms of resilience and transparency that is enabled to them through more decentralised and local energy generation and distribution. Additionally, the possibility for incorporating more renewable energy resources and the cooperation with other (local) energy communities emerges (Ahl et al. 2019; Goulden et al. 2014; Green & Newman 2017; Martiskainen & Watson 2009; Mengelkamp et al. 2018; Van Cutsem et al. 2020). Identifying which forms of consensus-building between local, public and private stakeholders are provided and how they are influencing the development process of the envisioned energy infrastructures becomes essential for understanding the changing landscape of energy markets in the future. Studying and reflecting on which motivations and intentions of stakeholders are colliding and the forms of relationships that emerge out of this network of stakeholders is hereby of

importance. Investigating this network of actors, relationships between them and the technical aspects of novel energy infrastructures and their development provides intriguing insights on the existing power relations, conceptions and social practices within the energy sector. This research focus will serve to investigate if, and to what degree, the proposed decentralised platforms for energy management and trading are challenging the existing power relations, practices and interactions between stakeholders. Mapping and analysing this socio-technical network thoroughly will provide useful insights for understanding the tensions between entities within it, as well as provide further knowledge on the transformation of infrastructures through the novel case of peer-to-peer energy trading.

The empowerment of citizens in local energy communities

Along with the conceptualised decentralisation of energy infrastructures and the promise of more efficiency and sustainability, a focus on more citizen activity and participation is presented as a crucial part of the ongoing transformation of the energy sector. Especially in the context of local energy communities, new energy infrastructures are conceptualised which should be citizen-centred and offer individuals new forms of interaction with their community and their energy market. Through the possibility of producing and sharing energy on their own, projects which aim at developing platforms for energy sharing and trading in local settings, often promise that these infrastructures will lead to more agency for citizens and thus make them empowered (Ahl et al. 2019; Li, Bahramirad et al. 2019; Lowitzsch et al. 2020; Mengelkamp et al. 2018). Examining how the power relations and forms of governance between citizens and other energy sector stakeholders are influenced or transforming through novel energy infrastructures, also encompasses to investigate such claims.

It hereby becomes important to investigate what forms of citizen engagement in local energy communities are envisioned by which stakeholders connected to the development of decentralised energy infrastructures. Are such infrastructures transforming or enabling new forms of citizen participation and agency in the planning, implementation and active operation of local energy infrastructures and markets? Furthermore, are they achieving the degree of citizen engagement that is conceptualised in the pilot projects aiming at democratising the energy sector, putting citizens at the centre of the energy transition and making them empowered prosumers instead of being mere passive consumers?

Apart from analysing the forms of conceptualised interaction with citizens by other energy sector stakeholders, it will be interesting to investigate the motivations of citizens for becoming engaged in such projects. In this light, it should be questioned if citizens are in fact interested in becoming a central part of this infrastructural transformation, and how they are incentivised. What are perceived risks and benefits of the proposed energy infrastructures for citizens that might hinder or advance their adoption of them? An extensive analysis on the forms of citizen engagement and potentially resulting novel forms of agency or relationships, will provide additional insights for understanding changes in power relations within the network of energy sector stakeholders, and the transformation of the energy sector as a whole.

Transformation to energy citizens

Thinking back to the three types of energy users – consumer, producer or prosumer – we consider the ways in which novel energy infrastructures centred on peer-to-peer energy sharing and trading might influence the role of users, changing them from mere consumers to prosumers and expanding their degree of agency further than in traditional centralised systems of transactions and energy distribution.

The first characteristic of peer-to-peer energy infrastructures, becoming stabilised, secured and remaining functional through the interactions and emerging relationships within them, is closely linked to users and other entities enmeshed with the network. Along the technical structures and design, a form of cooperation and embeddedness between entities appears to be present, which enables the functions of facilitating, securing and validating transactions, as well as recording transactions and distributing energy, through the network and its users itself. Furthermore, this leads to the transformation of such systems towards a structure where no intermediate entity or authority is needed to fulfil these functions. The decentralised novel energy infrastructure is thus highly dependent on entities within it to uphold its decentralised character (Ahl et al. 2019; Li, Bahramirad et al. 2019; Lowitzsch et al. 2020; Mengelkamp et al. 2018; Diestelmeier 2019).

The opportunity for users and communities to transform into self-sufficient citizen utilities, generating their own electric power, managing and trading it in more efficient, transparent ways, is incorporated in most envisioned novel peer-to-peer energy infrastructures. This is not just a secondary feature, but is one of the major pillars of the networks towards achieving higher degrees of decentralisation, democratisation and sustainability in energy markets (Ahl et al. 2019; Green & Newman 2017; Mengelkamp et al., 2018; Van Cutsem, Dac, Boudou, & Kayal, 2020). Additionally, such forms of transactive energy exchange and management are related to mechanisms within networks to incentive market participation and investments in local, sustainable energy production. Such rewards systems, empowering users and transforming their identity and behaviour, need further investigation (Ahl et al., 2019; Jiang, Zhou, Lu, & Yang, 2020; Li, Bahramirad, Paaso, Yan, & Shahidehpour, 2019; Lowitzsch, Hoicka, & van Tulder, 2020; Mengelkamp et al., 2018).

8.6.2 Discourses and socio-technical imaginaries

It has become more and more apparent that citizen and stakeholder engagement has a considerable role to play for sustainability transitions in general and energy transitions in particular (Bauwens et al., 2022; Grin, Rotmans, Schot, Geels, & Loorbach, 2010; Hyysalo, 2021). Participation of broad ranges of stakeholders exceeding the mere information or consultation level has become central to socio-technical change (cf. Arnstein, 1969; Hurlbert & Gupta, 2015), i.e., change that involves the co-evolutionary embedding of technologies in society (Grin et al., 2010; Kemp, Loorbach, & Rotmans, 2007; cf. Unruh, 2000). This understanding builds on the idea that technologies that are imposed on the envisioned users without engaging with them during the development has led to unintended usage, undesired consequences, or outright failure of technologies (Collingridge, 1979).

Acknowledging that stakeholders' views and interests matter in local energy transitions (Loorbach, 2010), means that understanding views, ideas, interests as well as stakeholders' visions of future energy systems is paramount to constructive and productive engagement in local energy transition projects (Kern & Rogge, 2018; Sovacool, 2019; cf. Spaapen & van Drooge, 2009). Ideally, these reflection processes occur during intensive engagement processes between innovators and intended users, which have been called 'bridging events' elsewhere, as they intend to bridge the differences of viewpoint between those introducing and those using the technology in question (Garud & Ahlstrom, 1997; Robinson, 2010). If intensive engagement is not possible, innovators need to find other ways of grasping how relevant stakeholders view the technology and its future. In other words, innovators must understand the different positions in the societal debate about the local energy transition as relevant for them. While the local energy transition has also been studied from the perspective of 'frames' (e.g., Bellamy, Chilvers, Pallett, & Hargreaves, 2022; Eaton, Gasteyer, & Busch, 2014; Lagendijk, Kooij, Veenman, & Oteman, 2021) or 'visions' (e.g., Braunholtz-Speight et al., 2021; Krzywoszynska et al., 2016), we will here focus on the 'discourses' and 'socio-technical imaginaries' at play in the local energy transition (Köhler et al., 2019; Sovacool et al., 2020; Turnheim et al., 2015). As one of the perspectives applied in the SERENE project, reviewing the literature that has dealt with both notions and the local energy transition will shed light on the normative societal debates going on as well as give insight in the potential views and interests of stakeholders about the topic. In the following, we define the two notions of 'discourse' and 'socio-technical imaginary'.

The notion of 'discourse' has played a role in philosophical, sociological, and linguistic disciplines and has relatively recently also been picked up by (environmental) policy scientists. This evolution is evident in the way the concept is defined. In a social-constructivist manner, discourses can be generalized as ways of talking about reality that involve specific sets of "ideas, concepts, and categorisations", which give meaning to otherwise disparate elements of reality (Brugger & Henry, 2021; Hajer & Versteeg, 2005). Some strands take engaging in discourse to be a social practice in itself, thereby making discourse a way of constructing a perceived reality, as well as being dependent on actors' social circumstances (Lassen, 2016; Wagenaar, 2011). While the notion of 'frames' relates to individual actors or actor groups at most, discourses represent a higher level of reality perception that "reflect the subconscious organization of collectively held values and mental models" (Parkins, Hempel, Beckley, Stedman, & Sherren, 2015). As such, certain discourses are the outcome of discussion and deliberation between actors bringing their own perceptions of reality to the table (Hajer & Versteeg, 2005). Furthermore, while 'hegemonic discourses' may exist in specifically bounded socio-spatial contexts, they are by no means monolithic, unchangeable structures (cf. Brugger & Henry, 2021). Thus, the societal interplay between agents and structures, or socio-technical regimes and landscapes and actors within them, entails continuous re-enactment, re-interpretation, re-negotiation, of the argumentative rationales enshrined in discourses (Brugger & Henry, 2021; Hajer & Versteeg, 2005; Lassen, 2016). From a policy and governance perspective, the ideas, concepts, and categorisations combined in discourses tell us about the perceived nature of policy problems, what acceptable policy solutions exist for them (and vice versa which solutions are unacceptable for those problems), which actors are relevant and how democratically policy processes

are to proceed; always within a specific socio-spatially delimitated context (Hajer & Versteeg, 2005). In sum, discourse analyses can entail deliberated realities, the process by which these realities come to be, and its characteristics (Wagenaar, 2011).

Compared to the notion of 'discourse', 'socio-technical imaginaries' have emerged relatively recently. Rising to popularity within the science and technology studies community in the past few decades, it has claimed an important place in the conceptual repertoire of that sub-discipline. Original thoughts about 'social imaginaries' took these to be a "common understanding which makes possible common practices and a widely shared sense of legitimacy" (Taylor, 2004, p. 23). Social imaginaries reflect the social, psychological and institutional processes that reality is constructed of, as well as how individuals situate themselves in a broader social world (Parkins et al., 2015). Socio-technical imaginaries, then, narrowed the scope of the broader term to "the way national actors legitimize science and technology investment, design, and deployment through mingling policy action with collective visions of a better future made possible through technoscience" (Eaton et al., 2014, p. 227). The most-cited definition of socio-technical imaginaries is "collectively imagined forms of social life and social order reflected in the design and fulfilment of nation-specific scientific and/or technological projects" (Jasanoff & Kim, 2009, p. 120; see also Burke, 2018; Cloke, Mohr, & Brown, 2017; Haddad, Günay, Gharib, & Komendantova, 2022; Mutter, 2019). Although the original notion focused on a collective, i.e., national-level, vision of how and which science and technology projects will contribute to a 'good society' in the future (Schelhas, Hitchner, & Brosius, 2018; Smith & Tidwell, 2016), several sources discuss the ways in which this national-level vision or narrative interacts with the local level, for example by stimulating coalition-forming, resistance or challenging de facto governance structures (see below).

Introducing technologies cannot be done by only taking into account the 'hard' system part of society, i.e., concrete energy infrastructures, finance, etc. Rather, a 'hard' systems perspective must be complemented with a view on the 'soft' systems side. This includes many more societal characteristics (see other sections in this report), but also the aforementioned notions of discourses and socio-technical imaginaries, as well as their materialisation in society. It is our understanding that the likelihood of successful co-development of more renewable technologies for the local energy transition is increased by understanding these cognitive structures among the relevant stakeholders.