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2 Executive Summary

Decentralized local energy is seen as key in achieving energy transition goals (Young & Brans, 2017). However, the success of socio-technical energy system transitions at the local level is influenced by general trends and contextual issues alike (cf. Koirala et al. 2016). While the general trends are inevitable or at least difficult to modulate in the short term, contextual issues can be addressed. Learning about such malleable contextual conditions can best be done by looking at specific empirical contexts.

This SERENE deliverable 3.2 considers the socio-technical dynamics of energy transitions, including their potential influence on the 'hardware' of energy technologies, which may play a role for the implementation of local citizen-centred energy systems. Specifically, it addresses the questions:

- Which obstacles and conditions are present in three local energy transition contexts regarding the local energy transition?

- Which conditions for stakeholder engagement are present or need to be developed in those same local energy transition contexts?

The SERENE project accompanies local energy system transitions in Skanderborg (Denmark), Olst (the Netherlands), and Przywidz (Poland). These three sites of local energy systems transitions are embedded in socio-technical systems, comprising both technical components (e.g., energy generation equipment) and social components (e.g., actors and institutions). Moreover, the transition of these local energy systems is seen as socio-technical systems change, referring to the technical and social innovations that are introduced to disrupt and change the incumbent systems in the demonstrators.

As energy transitions at the local level are confronted with various societal issues, we map these based on key actor interviews with local representatives of the transition sites (in the remainder, these are called 'demonstrator sites') and cross-referencing these with literature reviews from various social-scientific perspectives (e.g. socioeconomics, laws and regulatory frameworks, governance, urban planning, social acceptance, and societal debates). All thus generated obstacles and conditions are categorised using an existing framework which was adapted for SERENE's purposes. The issue domains in this framework include (1) technological issues such as energy efficiency, (2) socioeconomic issues such as a lack of the 'right' economic incentives, (3) environmental issues such as pollution, and (4) institutional issues such as trust, motivation, and continuity. Apart from enumerating and describing the current obstacles and conditions present in each of the transition sites (section 3), we also include a brief reflection on obstacles and conditions that were found to be relevant in the literature, but not (yet) present locally in order to predict the obstacles and conditions that the demonstration sites may encounter as the project progresses.

The second objective of this deliverable is a discussion of the conditions for citizen engagement. While many of the obstacles also affect citizen engagement, we therefore also discuss the role of innovation agents, such as SERENE project partners, in the governance of innovation processes (section 5). If the co-evolution of society and (energy) technology is to be taken seriously, a different mindset is required of

scientists that involves an inclusive and open-minded perspective. Besides briefly describing the scientific perspective on this, we also provide a very generic guideline to achieve greater levels of responsible involvement from citizens in innovation processes (section 5).

Assessing the obstacles and conditions in SERENE, shows that the contexts of the three transition sites are quite different from each other. Only a few obstacles and conditions are shared, and will, then, also play out differently. Depending on which stage of the innovation process that each transition site is in, the obstacles and conditions also differ per issue domain. For example, as in Przywidz, the energy monitoring technologies are currently being installed, so there are no social issues related to these technologies, yet. Currently, more issues are reported relating to institutions in that transition site. Regardless of the between-case differences, the findings present an opportunity for learning and the exchange of experiences between the sites. We conclude that while a deeper understanding of the local circumstances will further improve the support of the innovation process on the local level, the findings presented here already provide a good baseline from which to further engage in the co-evolutionary accompaniment of each innovation 'journey'.

1 Introduction

Decentralized local energy is seen as key in achieving energy transition goals (Young & Brans, 2017). To illustrate, in the context of varying local endowments of renewable energy sources (e.g. due to spatial configurations one region may benefit more from solar while the other more from hydropower), the energy transition may best be dealt with, though not exclusively, at the local level. According to the Intergovernmental Panel on Climate Change (2007, p. 288; in: Goldthau, 2014), a decentralized energy system will indeed result in reduced costs for transmission systems, efficiency gains, lower grid loss, and enhanced resilience on distributed generation. Moreover, energy transitions at the local level tend to intensify citizen and community participation, which in turn is key for raising awareness and acceptance of the energy transition more broadly (Beermann & Tews, 2017; Wierling et al., 2018).

However, the success of energy system transitions at the local level is influenced by general trends and contextual issues alike (cf. Koirala et al. 2016). Trends include increased electrification, rising distributed energy resources, ambitions towards a carbon-neutral energy mix, changing utility business models, and increasing customer engagement (ibid.). More importantly, local energy system transitions face technological issues such as the intermittency of renewable energy production, socio-economic issues including the willingness to pay and energy poverty, environmental issues like emissions or waste, and finally, institutional issues related to energy democracy or regulations (ibid.). Various studies have critically assessed such trends and issues (or: barriers, obstacles, factors, challenges etc.), for example focusing on certain geographical areas (e.g., Boon & Dieperink, 2014; Brummer, 2018; Magnani & Osti, 2016); on specific types of challenges such as regulatory ones or related to governance or business models (e.g., Herbes, Brummer, Rognli, Blazejewski, & Gericke, 2017; Hoppe & Van Bueren, 2015; Ines et al., 2020); or specified types of local energy system transitions such as grassroot initiatives, cooperatives or others (e.g., Tarhan, 2015; Capellán-Pérez, Campos-Celador, & Terés-Zubiaga, 2018). While the general trends are difficult to modulate in the short term, contextual issues can be addressed. Learning about such malleable contextual conditions can best be done by looking at specific empirical contexts.

Hence, this report, which has been developed for the EU Horizon 2020 project "Sustainable and integrated energy systems in local communities" (SERENE), explores the contextual issues in three demonstrator sites that have been selected specifically for the purpose of the project.[1] The contextual issues that will be explored are the concrete obstacles local stakeholders in those sites experience, as well as the conditions that are either already in place or that need to be created to make the introduction of more integrated local energy systems possible and even successful. Especially regarding the aspect of conditions, we zoom in on the ways in which stakeholder engagement can be stimulated in each of the demonstrator sites to do justice to the notion of co-creation of the local energy transition (Itten et al. 2021; Voorberg et al. 2015). This leads to two guiding questions, which this report addresses:

- Which obstacles and conditions are present in the three local energy transition contexts regarding the local energy transition?
- Which conditions for stakeholder engagement are present or need to be developed in those same local energy transition contexts?

[1] The technical aspects of each of the three demonstrator sites are extensively discussed in SERENE deliverable 2.1. Any societal aspects of relevance for now can be found in deliverable 3.1, which was published at the same time.

These questions will be answered from an interdisciplinary social science perspective. Energy transitions at any level are often studied as technical systems of solar panels, wind turbines, distribution grids, storage facilities and so forth. However, this does not sufficiently explain how energy transitions come about or what is obstructing them. On the contrary, the energy transition cannot be separated from its societal dimensions, such as regulations and legal frameworks; institutions and policies; spatial energy planning decisions; social acceptance of technology; economic business models of investments and revenues; and societal ideas, beliefs and motivations (Hicks & Ison, 2018; Hoppe, van den Berg, & Coenen, 2014; Moss, Becker, Naumann, 2015; Warbroek, Hoppe, Bressers, & Coenen, 2019; Young & Brans, 2017). Thus, this report draws from expertise in socioeconomics, laws and regulations, governance, urban planning, social acceptance, and societal discourses to understand this so-called 'socio-technical system' of local energy transitions. In doing so, the deliverable not only answers the two guiding questions, but also contributes to systematically integrating social science in studies on decentralized local energy.

This deliverable builds directly on deliverable 3.1. It also provides input for the remaining deliverables and tasks in WP3. There will also be useful knowledge for work packages 4, 5, and 6 of SERENE, especially considering the obstacles and conditions regarding citizen engagement, including the guideline presented in section 5. As a baseline assessment, it also serves as input for work package 7, where the outcomes of the innovation processes will be evaluated.

Accordingly, this report is structured as follows. After this introduction, section 2 focuses on our understanding of local energy transitions as processes of socio-technical change, and describes our approach of answering the guiding questions. Eventually, section 3 shows the obstacles and conditions we discerned, after which section 4 provides an overview of obstacles and conditions which are not actively discerned in the demonstrator sites but which may nonetheless become relevant in the future. Section 5 describes the conditions for citizen engagement that are partly derived from sections 3 and 4. Section 6 concludes the report with an overview and outlook. After the reference list, an appendix contains the literature review underlying this report.

2 Conceptual background and mapping approach

This section explains the framework that is used to map obstacles and conditions for local energy system transitions. It first provides an overview of our understanding of local energy system transitions as socio-technical change (see also SERENE deliverable 3.1). Second, it describes the approach we applied to map the obstacles and conditions in the three demonstrator sites.

2.1 Conceptual background

Understanding local energy systems as *socio*-technical systems implies that they involve not only technical components (e.g., power plants, transformers, grid infrastructure etc.), but also social components such as actors, organizations, institutions as well as economic and political frameworks (Van de Graaf & Sovacool, 2020). The technical and social elements of the system work together in such a way that they are "configurations that work" (Rip & Kemp 1998). Moreover, in the SERENE project, local energy system transitions are considered to be processes of socio-technical change. This refers to the process of transitioning from a fossil fuel energy system to a low carbon, citizen-centred and economically viable integrated local energy system.

The conceptual thinking we deploy for understanding the demonstrator sites and the transition processes they are involved in is derived from three well-known innovation studies frameworks: Multi-Level Perspective (Geels 2019), Transition Management (Kemp et al. 2007; Loorbach 2010), and Strategic Niche Management (Kemp et al. 1998; Schot & Geels 2008). One of the central aspects of these frameworks is understanding innovation as a *process* rather than an *outcome*. To disentangle the (most of the time) complex innovation processes, these frameworks utilise a view of three 'layers' in the innovation process (cf. Rip 2012). The first layer to consider is the 'niche', a protective space where novel products, services, governance arrangements, etc., can be experimented with (Smith & Raven 2012). In SERENE's demonstrator sites, this may encompass the configurations of inhabitants of Aardehuizen, the technologies they have applied to construct their houses, the high-tech energy technologies there, the knowledge they have about living sustainably, the Dutch laws and regulations they are subject to. To a certain extent, niches enjoy processes of (a) shielding them from the competition with incumbent socio-technical arrangements (e.g. the exemption ruling for Aardehuizen), (b) nurturing them through subsidies or participation in European research projects, and (c) empowering them through providing technology, skills, and expertise to help them take a next step in transitioning to a lower-carbon community (ibid.). The second layer is that of the socio-technical regime, essentially the dominant practices, rules and technologies that provide stability and reinforcement to the 'incumbent' socio-technical systems (Geels & Raven, 2006; cf. Fuenfschilling & Truffer 2014). Key in the context of the SERENE project is that this definition extends the understanding of an established regime from a technological to a socio-technical regime. Finally, the third layer of the landscape entails political, cultural and economic dynamics and events that are arguably outside the socio-technical regime in question, but may impact it nonetheless. For local energy systems in SERENE, the landscape is for example characterized by geopolitical dynamics, general environmental awareness, social values, political beliefs etc.

These three layers constitute the socio-technical system. Innovation processes attempt to change the regime, i.e. the way things are currently done. There are various ways in which this regime change can be effectuated (Geels & Schot 2007). This includes events in the landscape that destabilise the regime, such as the instrumentalization of energy sources for geopolitical ends, or the emergence of a matured niche that is ready to overtake or substitute certain regime technologies or processes (e.g. smart meters or blockchain-supported community-level energy trading).

For SERENE, the socio-technical regimes in question are the local energy systems as they are now, including the laws and regulations, existing technologies, and social practices surrounding them. The niches are the smart, integrated technologies that are applied in each demonstrator site along with the skills, expertise, and practices that are required to make them a functioning 'configuration'. For example, in Przywidz, there is a local energy system, in which a considerable share of households rely on individual coal stoves. This entails practices of heating, buying coal, etc. The niche would be the attempt to broaden the collaboration between community members and modernise the way energy use is monitored. None of these elements is innovative in itself, from a generic point of view (citizen collaboration is already going on in other places, and the technologies are not novel in themselves). However, the way these elements are attempted to be assembled into a configuration that works *in this location* (vis-à-vis the resistance of the current socio-technical regime) is the innovative aspect of the Przywidz demonstrator site.

To be sure, these concepts do not 'explain' socio-technical change, but allow us to identify the elements of the socio-technical system and observe how they relate to each other. This discussion on socio-technical systems change provides the conceptual lens that is applied to local energy system transitions in this deliverable, as well as in the previous deliverable.

2.2 Mapping approach

The mapping of obstacles and conditions occurred through a two-stage process (Figure 1). First, we reviewed the scientific literature for known obstacles and conditions in the local energy transition and local integrated energy systems. We reviewed literature from various social science perspectives, including socioeconomics, laws and regulatory frameworks, governance, urban planning, social acceptance, and processes and content of societal debates. The conceptual background of each of those perspectives is extensively introduced in deliverable 3.1 and will not be described in-depth here.

However, the detailed results of the literature review can be found in the Appendix. This review of the literature was combined with a framework for integrated community energy systems as introduced by Koirala et al. (2016) and yielded an adapted framework suitable for the realities we observed in the demo sites. This framework has four key issue domains that are listed in Table 2.[2] Technological issues include all issues related to energy hardware, grids, and other infrastructure. Socio-economic issues enumerate those issues dealing with social, organizational and market problems the demo sites are facing. Environmental issues incorporate all environment-related issues.

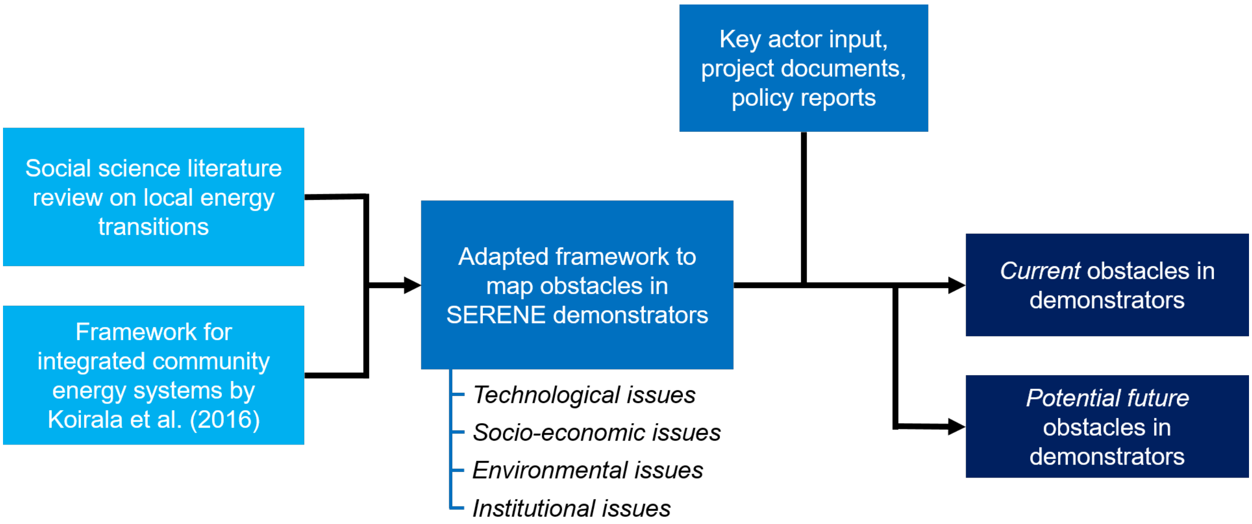

Figure 1 Mapping approach

In the next step of analysing these outcomes we cross-referenced the findings of the literature review with empirical findings from key actor input, project documents and policy reports. Key actor input was organised through group interviews with representatives of each demonstrator site to elicit the obstacles and conditions *currently relevant* for all. This meant that some of the issues identified in the literature would *not currently be present* at the SERENE demonstrator sites. Thus, one might conceive of other issues that are typically associated with integrated local energy systems or novel energy technologies (e.g. battery safety), but if these were not mentioned as currently relevant, they don't appear in this table.[3] The interviews took approximately two hours and took place between 24th May and 3rd June 2022. The affiliations of the participants in the key actor interviews are reported in Table 1.

Table 1 Affiliations of participants in the key actor interviews per demonstrator site.

Hylke & Låsby, Skanderborg (DK)	Aardehuizen & Vriendenerf, Olst (NL)	Przywidz, (PL)
1x Skanderborg municipality 2x NeoGrid 1x Aalborg University	1x Aardehuizen community 1x Saxion 1x University of Twente	2x IMP Gdańsk 1x Stay-On

[2] There is no explicit mention of business models or business cases in this framework. We discuss these in the dedicated deliverable 3.4. However, wherever these come up, we mention any issues directly or adjacently related to business models.

[3] We added a table listing other potential issues and a brief reflection in section 4.

Table 2 Key issue domains related to local energy system transitions (adapted from Koirala et al. 2016; issues marked with a '*' were added or adapted).

Technological issues	Socio-economic issues	Environmental issues	Institutional issues
1. Renewable energy generation* 2. Multi-carrier energy system (heat-power, transportation by EVs)* 3. Energy efficiency 4. Storage 5. Local balancing of supply and demand 6. Local flexibility and impact on larger energy system	1. Community engagement 2. Economic incentives 3. Willingness to pay 4. Split-incentive problem 5. Energy autonomy and security of supply 7. Demographic characteristics* 8. Equity*	1. Environment and climate change 2. Pollution* 3. Nature & biodiversity* 4. Public space*	1. Trust, motivation and continuity 2. Energy democracy 3. Ownership 4. Locality 5. (Self-)governance 6. Institutional design 7. Roles and responsibilities 8. Opportunity structures* 9. Discourses and socio-technical imaginaries*

3 Obstacles and conditions for local energy system transitions

This section reports the findings of obstacles and conditions per demonstrator site. Each type of issue – technological, socioeconomic, environmental, and institutional – is organised through an overview table showing whether an obstacle or condition is currently relevant for a demonstrator site, and a description of the issues. We do not distinguish between obstacles and conditions, as they are understood as two sides of the same coin. In other words, an existing obstacle calls for certain conditions to be created, and existing conditions that are conducive to citizen-centred local energy transitions imply the absence of an obstacle relating to the issue in question. We have attempted to label the obstacles and conditions as neutrally as possible in the tables and describe their nature in the text.

3.1 Technological issues

The development of infrastructures for local energy communities is met with an array of technological obstacles and issues, for example related to the technical characteristics of the infrastructure such as technical devices and grid infrastructure. However, there are also aspects to take into account that are at the intersection of technical and social issues (Table 2). For all these issues, it holds that their absence in our tables does not mean they do not play a role at all, but that they were not mentioned as current issues relevant for SERENE.

3.1.1 Hylke & Låsby, Skanderborg (DK)

In the current energy policy situation revealing the internationality of the energy system, the rising energy prices have pushed Denmark to move away from natural gas. Denmark's future vision is more and more gas-free. Although this is the general trend and there will be opposing voices, such a vision of fossil-free energy is required to set a collective goal. Furthermore, representatives of the demo sites perceive the Danish energy future as electric and organised at the district level, so not fully decentralised. We observed that there is a focus on supply-side energy technologies, such as heat pumps, and in the future also heat storage thereby increasing demand response possibilities. This is associated with the focus of the research project SERENE, but may be a too limited perspective, given that combinations with nature-based solutions can create synergies that also influence the local energy system positively.

Currently, more than 60% of Skanderborg Municipality's consumers receive their heat from district heating. District heating is also very popular in Denmark at large, due to its usually low cost and reliability. The continuously low cost partly stems from the fact that national law prohibits companies to generate profits from district heating, which reduces the attractivity of this market for commercial companies. Furthermore, while some district heating plants in Denmark are owned by a municipality, the four district heating companies in Skanderborg Municipality are all owned by their own consumers. The wood-based heat production of three of these plants does not involve electricity production. Only one of these four plants has originally combined electricity and heat production. Just like with other Danish stand-alone plants combining electricity and heat production, this plant started off with heat as a byproduct from the production of electricity, resulting in a low heat price. However, electricity production from wind, sun and waste in Denmark has risen such that heat has become the main product of combined heat and electricity plants, with electricity as the by-product of this process. Consequentially, heat consumers were faced with an increased price. Since then, the plant has been converted from heat production with natural gas engines to using groundwater heat pumps and solar heat. The latter technologies account for approximately 80% of the plant's heat production. Although this has led to a lower and acceptable price, the plant is still in fierce competition with individual heat pumps.

In areas without access to district heating, there is also some demand for individual heat pumps where they replace fossil-fuel-fired household level burners. Actually, this is the technological retrofitting considered for SERENE's Hylke area, which is outside the range of a district heating system. However, Skanderborg municipality would caution households in areas currently without district heating to take into account developments in that area before rushing into installing individual heat pumps. With the path dependence of a well-developed district-level heating system, stakeholders should not jump to conclusions that innovations at the household level are the way to go, as they are noisy, ugly, and less cost-effective in replacing than a district-level system.

The discussions about the 'right' level of energy transition focus is ongoing, as district heating represents a 'proven technology' in the Danish context. People perceive it as a reliable source of heating and appreciate the ease of fixing technical issues. This leads to trust in the experts in charge of the district heating system. Representatives of the demonstrator site expressed good hopes of being able to scale up what is learnt at the local level regarding energy technologies to higher levels.

In terms of demand-side management, Danish distribution system operators (DSOs) are required to install smart meters to all homes and businesses. In 2020, the smart meter installation rate was 99.9 percent. The Danish Transmission System Operator's (TSOs) IT platform 'DataHub' has been designed to record data for gas, heat, and electricity consumption with the intention to optimise sector coupling, but is, for now, only used for the latter.[4] The data can be transferred every 15 minutes, and TSOs and DSOs are in charge of data storage and transmission (Danish Utility Regulator 2020).[5]

3.1.2 Aardehuizen & Vriendenerf, Olst (NL)

The two Dutch demonstrator sites in the municipality of Olst are community-led eco-housing projects. Both communities thus defined their own moral values based on sustainability and designed their community and infrastructure accordingly. Such communities are in favour of local renewable energy generation and go to great lengths to organise their development and implementation through proactive participation in stakeholder group meetings, engagement with external and surrounding citizens and opening themselves up to visitors and criticism. Aardehuizen and Vriendenerf have already achieved a high level of self-sufficiency, covering their electricity demand with local photovoltaic and their heat demand with heat pumps, wood boilers and solar thermal systems. A representative of the Aardehuizen community reported that the community current produces a surplus in electricity, which has led to a change in perspective within the community over the past years. This change in perspective relates to the realisation that the community could supply their surplus of renewable energy to the immediate surrounding village, thereby saying farewell to more extreme forms of energy self-sufficiency. But in order to do this, the external grid needs to be used and there are regulations that restrict feeding electricity back to the grid. Community representatives currently envision the possibility of "giving" the surplus energy to their neighbours and thereby develop a reciprocating relationship. Additionally, the community is open to optimise the energy supply side further by incorporating upcoming technologies. This may include efforts in energy efficiency that particularly focus on solar energy. Although this was not discussed during the stakeholder workshop, citizens' different practices concerning the use of appliances complicate a demand shift.[6]

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[4] Citizens' opinions about these smart meters are, for now, unknown, but will be elicited with a survey in the near future.

[5] Although representatives of the demonstrator site did not observe any privacy-related problems at the moment, they would welcome information regarding the relevance of privacy-related issues, as this may complicate the monitoring of demand response in the future.

[6] This will also be taken up in the survey and following interviews.

Although forms of EV usage and charging are becoming more and more accepted and feasible, the development and facilitation of such infrastructures remains challenging for communities due to unclear or limiting regulations. Both Aardehuizen and Vriendenerf are enthusiastic about building EV charging stations and using them in a shared community manner. Aardehuizen representatives explained that for now, the roof of the carpark where the future charging station will be, is used as a community energy production plant (PV panels) that produces a surplus of energy for the community. However, regulatory issues emerge from this, such as not being able to own this infrastructure as a community and being able to sell or use energy from it directly. In the current arrangement, the carpark building is owned by a single individual from the village that sells the excess energy as an individual to the local energy retailer. In an arrangement starting 2022, ownership of the carpark including the PV-production plant will be transferred to a new foundation with a board whose members are inhabitants of Aardehuizen. After paying back the investment, the surplus will be shared among the community. The plans for the development of a fully community owned and shared EV charging station are for now uncertain and will become a challenging process in the coming months/years.

Smart meter regulation in the Netherlands is one of the most flexible in the developed countries. For instance, smart meter installation is not mandatory and energy supply companies can only collect energy consumption data every month for billing unless there is explicit consent for collecting data more frequently (Lee & Hess 2021). During a community workshop, participants from one household showed concerns for health- and privacy-related issues regarding the supposed electro-magnetic field caused by smart meters, which is a much more common phenomenon and concern in the United States (cf. Hess 2014).

As seen in Aardehuizen, there is a possibility of single members of a community taking on the role of spokespersons. Such spokespersons are highly active, engaged and hold a high degree of technical versatility and knowledge. The spokesperson of the community is then tasked with ensuring that the devices will not get too technical and that community desires and concerns are heard and discussed (e.g. concerns of radiation coming from devices). On the one hand, this shows community members' trust in this kind of knowledge broker. On the other hand, in other cases it may represent a risk, if too few people have the advanced knowledge and skills in dealing with the relevant energy technologies and other actors.

3.1.3 Przywidz, (PL)

The findings on technological issues in Przywidz are scarce for now. Given that project partners are currently in the stage of installing the energy technology and monitoring technologies, the focus is on developing an approach to involving stakeholders. Nevertheless, representatives of the demonstrator sites indicated the presence of NIMBY attitudes, especially related to a recent attempt to construct windmills in the neighbourhood. This may point to a certain degree of distrust in larger-scale energy initiatives. Especially, there is a path dependence of very decentralised fossil energy generation through coal stoves. For now, alternatives are expensive and to some extent unknown. Nevertheless, many houses in Przywidz have recently installed collectors for hot water and photovoltaics as it became economically more interesting. This new amount of photovoltaics results in a need for improvement of the general situation. Recently, an electric public transport bus has been introduced reduce emissions and promote alternatives to fossil fuel cars. Project partners are hoping to be able to control the charging of the bus at some point during the project. However, the purchase of an electric car that supports V2G is also planned within SEREN, and this vehicle will be employed as energy storage, too. The usage of the car as a battery will be a scientific experiment as its energy capacity will be neglectable compared to the other SERENE activities, such as the fluid-flow battery to be installed in Arena Przywidz or the Li-ion battery installed by Energa.

Poland plans to install smart meters to 80% of end users by 2026 (International Trade Administration 2022). Currently, Energa-Operator has installed over 1.54 million smart meters. Furthermore, Tauron

Dystrybucia has installed 820,000 smart meters (14% of all their meters), Stoen Operator has installed 130,000 (12%), PGE Dystrybucia has installed approximately 460,000 (8.3%), and Enea Operator has installed around 156,000 smart meters (7%) (Elżbieciak 2022). Regarding renewable energy, there is a big demand for PV installations due to market uncertainty. This is particularly the case since July 2022, when a regulatory change from net metering to net billing was introduced, which reduce the market for new installation for few months. At the time of writing (August 2022), the installation rate is increasing again because of high energy prices (Derski 2022). We plan to use survey data to complement the arguments made in this paragraph in future deliverables.

Table 3 Technological issues mentioned explicitly during the key actor interviews.

		Obstacles and conditions	**Sites of local energy transitions**		
			Hylke & Låsby, Skanderborg (DK)	**Aardehuizen & Vriendenerf, Olst (NL)**	**Przywidz, (PL)**
Technological issues	**Renewable energy generation**	Community-level attitude towards renewable energy generation (e.g. wind farms and other specific technologies)		X	X
		Perceptions about role of fossil fuels in the energy transition	X	X	
	Multi-carrier energy system (heat-power)	Data management regulations complicate demand response systems and possibility of smart grids	X	X	
		Making future visions of the energy system explicit supports a constructive debate	X		
		Uncertainty about short-term and mid-term development and functionality of energy technologies, and their local level deployment	X		X
	Energy efficiency	Preferences for when to use energy complicate demand shift and increased energy efficiency		X	X
	Storage	Energy storage solutions (e.g. home batteries or electric vehicles)	X	X	X
	Local balancing of supply and demand	(Newly installed) meters must be smart, without option to opt-out	X		X
		Varying public responses to smart meters	X	X	
		Privacy and security are challenging societal acceptance of smart meters	X	X	
		Health problems attributed to electronic appliances (e.g. smart meters or inverters)		X	
		Discourse is focusing on supply-side energy technologies and/or local demand	X	X	X
	Local flexibility and impact on larger energy system	Flexibility technologies require advanced knowledge and skills of consumers, which local energy communities may not possess	X	X	X
		Perceptions on the scale at which energy technology innovations should take place (e.g. household vs. system)	X	X	
		Discussions of scale of energy production	X		

3.2 Socioeconomic issues

The socioeconomic issues that are relevant in the three demonstrator sites include:

- Community engagement,
- Economic incentives,
- Willingness to pay,
- The split-incentive problem,
- Energy autonomy and security of supply,
- Demographic characteristics, and
- Equity (see Table 3).

3.2.1 Hylke & Låsby, Skanderborg (DK)

The ultimate membership of 'the community' in the Danish demonstrator sites, is not yet determined. For now, there is one site with existing buildings that will be retrofitted, and one where SERENE will contribute its expertise to a neighbourhood that is still to be constructed. Thus, there is a clearer perspective on who the targeted citizens are and what 'the community' will be in the former than in the latter. In the existing site, involvement of those citizens should be realized. However, we gathered from representatives of the demonstrator site that inhabitants of the existing households, who are all tenants, will be confronted with the changes as the SERENE collaboration is initiated through the landlord. This construction, which is realized through clauses to that effect in rental contracts, pre-empts the split incentive problem. The split incentive problem describes situations in which tenants and property owners may have different responsibilities regarding energy consumption, e.g. choice of energy provider or consumption behaviour. As the municipality leaves this process to the property owner and tenants, in SERENE, the new local integrated energy system at the existing site will become a market mechanism without governmental involvement. Whether such a top-down measure will turn out to be procedurally just, will depend on the impact the changes have on the energy practices of the tenants. However, what can be said is that the strong involvement of the property owner in the design and management of the local integrated energy system means a probably very limited emergence of the bottom-up dynamics that are well-known to occur in Nordic urban planning processes and that are conducive to urban commoning initiatives. Commoning initiatives focus on energy as a common good and community organisation. Ultimately, such initiatives may still emerge, but they would need to overcome the obstacles of unclear roles of residents among those of the private and public sector. Due to this unclarity, perceived fairness and/or justices have to be taken into serious consideration. It remains to be seen how the transition from the Nordic planning paradigm to a more traditional "business"-minded running of the resulting buildings will work out in the perceptions of tenants.

It is fortunate in this respect that Danish citizens are reported to be interested in sustainability, in general, although costs always play a role in the background. In 2019, there were 39 electricity companies that Danish consumers could choose from (Danish Utility Regulator 2020). This may have resulted in lower pricing for consumers as market players engaged in competition. With energy prices soaring recently, this image may have somewhat shifted towards a higher importance of energy costs. The global energy markets and politics cannot be denied as an external factor influencing the energy discourse in Denmark. Hence, representatives from the demonstrator sites are eager to engage with (potential) inhabitants to explore financial and practical impacts of the envisioned technological changes.

The view on regulations and economic incentives may be more problematic. One of the envisioned SERENE demonstrator sites could not actually be included in the project due to delays in the municipal zoning procedures. Regulatory obligations regarding public participation have also led to projects not being realised as inhabitants objected to changes deteriorating their living environment, for example, when a project was to block the line of sight to a church. These are concrete examples of how public participation can lead to longer and more complicated decision making processes. Similarly, as a representative from the demonstrator site mentioned, subsidies targeting the retrofitting of individual households may, in turn, disincentivise joint initiatives, such as innovating the established district heating system. Given the low influence of SERENE on this kind of economic incentives, citizen engagement would need to focus on the argumentative side of convincing citizens to engage in commoning initiatives.

3.2.2 Aardehuizen & Vriendenerf, Olst (NL)

The demonstrator sites in Olst comprise communities that were purposefully created with a common goal: becoming self-sufficient and as sustainable as possible. The members of the community are slightly older and can be considered to be more sustainability conscious compared to the general population.[7] While self-sufficiency has by now been achieved in terms of energy, the common goal and community structure has led to high social cohesion. The robust social structure allows the two communities to go to great lengths in making their living environment more and more sustainable. There are some technological projects planned, such as exploring energy storage opportunities in electric vehicles or home batteries. The knowledge on these technologies is often mediated by a spokesperson representing the community in the SERENE project. But the main interest right now is whether feeding their surplus renewable energy back into the grid for compensation would be financially feasible and profitable. Therefore, they can largely do without market competition of energy companies and their prices. One of the goals is to build a flexible community energy market for local self-sufficiency. Such a market desirably encompasses a dynamic pricing system to account for different neighbourhood sharing situations. This way, the community could see some return on investment from a market-based thinking perspective. Unfortunately, realising this vision is currently hindered by existing regulation regarding the role of energy providers in the Dutch energy market. The bottom-up view the community cherishes is, in this sense, incompatible with the top-down, centralised view ingrained in spatial planning and energy management institutions in the Netherlands.

Aardehuizen representatives emphasised the importance of their feeling of embeddedness in the municipality of Olst. Even among the inhabitants of Aardehuizen, who are highly motivated to engage in reducing their climate and environmental impact, return on investment and the underlying business case is important. Costly (technological) changes are still only acceptable, if they are at least budget-neutral when taking into account subsidies or energy savings. Nonetheless, Aardehuizen's injabitants consider their energy surplus not (only) as a technological thing, but very much as a social thing, too. The thought of giving away the surplus to the surrounding neighbourhoods testifies to this (see section 3.1). The community also engages intensively in outreach activities, such as guided tours through the neighbourhood, or open days, in which outsiders, who happen to come from all over the world, can experience the achievements and living conditions first-hand. The inhabitants are keen on sharing their experiences and not to be seen as some strange group of people living in a way that is only for 'the happy few'.

[7] Because their demographic characteristics affect the residents' attitude and behaviour towards energy transitions, the survey planned in the context of SERENE's Work Package 3 will collect demographic data as well as participants' sustainability and energy related attitudes.

Table 4 Socioeconomic issues mentioned explicitly during the key actor interviews.

		Obstacles and conditions	Sites of local energy transitions		
			Hylke & Låsby, Skanderborg (DK)	Aardehuizen & Vriendenerf, Olst (NL)	Przywidz, (PL)
Socioeconomic issues	**Community engagement**	Increased involvement of society is required and stimulated (e.g. through attention for sustainability and local production)	X		X
		Individual drivers to participate in the local energy transition differ		X	X
		Regulatory obligations to involve participants leads to longer and more complicated decision making processes	X		
		Community engagement may not align with top-down view of spatial planning institutions	X	X	X
		Market competition among energy service companies and government support for transition programs are required		X	X
		Embedding of the community in its social surroundings and feeling of a collective purpose		X	X
	Economic incentives	Economic incentives and regulations need to be aligned to avoid perverse influence on local energy systems (e.g. a policy with the ambition of achieving transitions in the local energy system must be complemented with subsidies on the desired household or company behaviour or taxes on undesired behaviour)	X		X
		Influence of global energy markets and politics	X		X
		Thinking in terms of cost-effectiveness and return on investment		X	X
	Willingness to pay	Willingness to pay for local and/or sustainable energy varies strongly and depends on the individual situation (considering environment, demographics and housing type)	X	X	X
	Split-incentive problem	If responsibility of energy consumption is split between tenant and property owner, this can lead to sub-optimal behaviour (overconsumption or underinvestment)	X		
	Energy autonomy and security of supply	Motivations for pursuing energy autonomy in local energy systems range from environmental to geopolitical (e.g. climate change, war or terrorism)		X	X
	Demographic	Role of knowledge, motivation, community cohesion, and geographical	X	X	X

		Obstacles and conditions	Sites of local energy transitions		
			Hylke & Låsby, Skanderborg (DK)	Aardehuizen & Vriendenerf, Olst (NL)	Przywidz, (PL)
	characteristics	context in social acceptance towards (local) energy transition			
	Equity	Distribution of costs and benefits across socio-economic and socio-spatial groups	X		X

3.2.3 Przywidz, (PL)

The Polish case appears to be governed by a top-down urban planning paradigm emphasising the local and higher-level governmental initiative and responsibility to ensure the provisioning of urban sustainability as a public good. The formation of an energy cluster, a specific organisational form promoted by the Polish national government for a few years now, is one of the main ambitions of the demonstrator site. This initiative is led by the municipality. The perspective taken is that of the DSO. Individual households are taken into account as far as their activities influence the local grid, e.g. through installation of household-level photovoltaic systems. Furthermore, improving the energy performance of a local school, sports centre, and sewage plant is also in focus.

A tradition of self-organisation and momentum for the appearance of "urban commoners" who will co-create and co-manage the local integrated energy system as a common good seems to be rudimentary or budding at best. Potential governance arrangements involving the community and the municipality need to be explored. In this context, it is also worth noting that the value households attach to local integrated energy systems may be rather low, which may translate into low willingness to pay for such initiatives.

The notions of 'community', 'sharing', 'common culture', and 'common problems' seem to play a marginal if not absent role in the local discourse in Przywidz. People are currently busy with maintaining their own quality of life, including the procurement of energy fuels. Nevertheless, attempts are being made by SERENE to spark awareness and trigger interest among citizens in organising the energy system in a more common way. As we gathered, financial motives play a stronger role in citizens' decisions to act on their energy systems than sustainability motives. For example, the recent rising energy price has led to a surge in the number of PV installations. Representatives of the demonstrator site state that there were 4000 requests per day up until 1st May 2022, but that number has since dropped to 4 per month due to the change from net metering to net billing. When installations started to pay off again due to increasing energy price on the market, the number recovered. These developments occur in the context of an energy market that can be characterised as hectic; with attempts to halt the rise of energy prices by limiting buying from national fuel stocks (but not from private ones), investors buying coal stocks limiting their availability, or the national coal supplier limiting how much can be bought at once due to problems in fuel supply chains. Although this situation may indicate a window of opportunity for promoting more sustainable energy systems with lower carbon emissions which will also become more cost-effective, there are counter movements, too. First, people with wood stoves will continue to use them more indicating a step backwards, rather than towards more sustainable energy systems. Second, the government decided to implement subsidies restricted to coal users, which may lead to people falsely declaring to use coal to acquire extra income. Third, people are rushing to install heat pumps that suffer from low availability due to supply chain issues. Finally, for sustainable energy technologies, it remains important to emphasise promises of financial gains or savings through the new infrastructures. Finances are reported to be the main perspective through which energy technologies are viewed in either a positive or negative light.

3.3 Environmental issues

Four categories of environmental issues were discerned in the three demonstrator sites (Table 5):

1. Environment and climate change,
2. Pollution,
3. Nature & biodiversity, and

4. Public space[8]

3.3.1 Hylke & Låsby, Skanderborg (DK)

In general, environment and sustainability are strong motivators for the representatives of the demonstrator site. At the demonstrator sites, the developer and/or owner of the envisioned community space appears to have a strong degree of spatial control, which is realised via the pre-programmed uses of the designed space and/or the property rights of those spaces. On top of that, we observed during the workshops that the housing developments are realised with a traditional view of energy as a private market good, mostly through the private sector. Although the planned renewable energy system envisions the participation of the community, aspects such as design and management options appear to be a top-down undertaking. These design choices will allow limited flexibility to configuring living spaces that integrate both environmental and energy considerations through spatial design, at least due to the communicated ownership structures. In terms of the debates, solutions to prevent noise pollution were specifically mentioned by the municipality as an important aspect. The municipality, thus, acts as the actor responsible for taking into account the interest of others surrounding the demonstrator site.

3.3.2 Aardehuizen & Vriendenerf, Olst (NL)

Also in the Netherlands the sustainability and environmental impact are highly valued. Climate change impacts and biodiversity effects of nitrogen deposition have figured prominently in recent debates, thereby only confirming the demonstrator communities' ambitions and convictions. Such ambitions and convictions similarly impact how the community embraces new energy technologies. One of the uncertainties or undesirabilities in regulations currently pertains to the ownership of buildings that still have to be individual and cannot be collective. Any changes in this would be highly anticipated. Another example relates to local air quality. When they built their neighbourhood in 2012-2013, the future inhabitants of Aardehuizen decided to cover their heating demand with wood-burning stoves as they worked hard to avoid the use fossil fuels. At the time, this was considered a highly sustainable heat source. Besides not having a zero-CO_2 footprint, it has become clear that replacement rates of forests are too low resulting in a loss of biodiversity. Moreover, within and outside the Aardehuizen neighbourhood, inhabitants have started complaining about nuisance and health issues relating to air pollution from the (improper) burning of wood. National-level regulation on indoor air quality and wood stoves is to be expected.

3.3.3 Przywidz, (PL)

One representative mentioned that apart from in specific circles, there is no serious discussion about climate and that "people don't see it as an everyday problem".[9] In general, there are Przywidz inhabitants who are interested in the environment (mainly a hedonic view on nature/biodiversity, not so much climate change), but also some that are not interested at all. While a climate change debate does not only seem to be absent on the local level, but also on 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, as younger generations are more aware of the issue and value a beautiful landscape, partly owing to ecology classes at schools.

[8] While issues relating to nature and biodiversity were not included in the original framework , we relabelled 'emission' to 'pollution' and 'spatial' to 'public space'.

[9] This can be a potential focus for the survey in Poland – to see how sustainability affects people's attitudes (if the public are interested in climate change issues and whether it can work as a motivator for sustainable energy transitions).

Furthermore, the fact that smog has been a prominent environmental hazard in the region, but has reduced after industrial renewal/discontinuation, could be turned into a trigger for community members to engage in community energy.

The Polish case will possibly run into obstacles surrounding the synergies between energy planning, on one hand, and environmental and climate adaptation planning, on the other. Although not explicitly discussed during the interview, we see a combination of a strong top-down planning approach with a concurrent absence of indications for community self-organisation.

Table 5 Environmental issues mentioned explicitly during the key actor interviews.

		Obstacles and conditions	Sites of local energy transitions		
			Hylke & Låsby, Skanderborg (DK)	Aardehuizen & Vriendenerf, Olst (NL)	Przywidz, (PL)
Environmental issues	**Environment and climate**	Local energy communities benefit from integrating nature-based solutions, ecosystem services, and climate architecture on top of sustainable energy technologies	X	X	X
		Accepting smart grids and smart meters depends on moral values related to the environment and climate	X	X	
		Role of global challenges such as climate change in debates		X	X
	Pollution	Role of direct impacts of noise, greenhouse gasses, and particulate matter on quality of life in debates	X		X
	Nature & biodiversity	Awareness of and interest in nature and biodiversity issues			X
	Public space	Spatial regulations including rules for siting energy production locations or building permits may obstruct local energy projects	X	X	X

3.4 Institutional issues

The categories of institutional issues include trust, motivation, and continuity, energy democracy, ownership, locality, (self-)governance, institutional design, roles and responsibilities, opportunity structures, and discourses and socio-technical imaginaries (see Table 5). The latter two were added to the original framework.

3.4.1 Hylke & Låsby, Skanderborg (DK)

The institutional situation regarding community energy is shifting in Denmark. The country has a long history in largely consumer-owned district heating systems, which represents fertile ground for further developing forms of energy systems exceeding the household level. This can empower citizens and communities and function as the basis of coalitions. Another factor adding to the momentum in the Danish institutional landscape is the recent adoption of new legislation transposing the relevant EU directives, such as the revised Renewable Energy Directive or the Internal Market in Electricity Directive, and covering the notion of 'energy communities' for the first time. What the practical impact of this framing of 'energy communities' will be on the local level and how it will impact the developments envisioned by SERENE, remains to be seen. Unfortunately, for now, this does not change the fact that communities are currently not allowed to share energy and that selling can only occur through a single provider.

In terms of relevant actors, key roles and responsibilities go to institutions and actors at the local level, including local governments, communities and companies (see deliverable 3.1). The municipality of Skanderborg appears to be the driving force behind the local energy system transition. Yet, the municipality recognizes that it also has to engage in collaborations with local companies on the one side and the local community on the other side. In other words, representatives of the demonstrator site consider collaboration and networking as a condition for the local energy system transition they seek to enact. However, it is also experienced as a potential obstacle. For example, the Danish demonstrator has to deal with two DSOs instead of one (one for each demonstrator site), which is not ideal for progress in the project. Furthermore, representatives are concerned about getting the consent of local customers – i.e. the local community. It must be noted, however, that the representatives expect the additional work to be minimal and that these obstacles can certainly be overcome. The fact that the process is not originally designed to be a bottom-up process but to remain in the hands of the property owner cannot be omitted as a potential obstacle in citizen engagement. Thus, developing governance arrangements that involve citizens in a constructive and productive way is perceived to be difficult, but necessary. To become perceived as legitimate processes, such arrangements must include the whole range of discourses conceivable in Denmark, from idealist to pragmatist. To enable urban commoning activities involving energy commons, there needs to be more formal room for the development of community structures, along with support for identifying as a community the potential for social (in addition to monetary) value creation.

3.4.2 Aardehuizen & Vriendenerf, Olst (NL)

In the Dutch demonstrator sites, the communities themselves are the driving force behind the local energy system transition. For both Aardehuizen and Vriendenerf, the respective community can be seen as a coalition or a form of bottom-up social movement because of their distinctive characteristics and values. It is made up of a group of people that are residing in a specific location – a neighbourhood of the village of Olst – because they want to minimize their sustainability impact. In fact, social cohesion and a common vision of a sustainable future in the Netherlands were crucial for starting both eco-housing projects. Self-sufficiency and independence are the dominant values for these communities. Models for self-governance and self-organization appear to be a key condition for the representatives of the Aardehuizen community, which already has its own organizational principles and policies in place. Simultaneously, the community recognizes that it remains dependent on the surrounding system of institutions and actors to take away barriers or to make certain things happen for their local energy system transition – whether they like it or not. Just like in the other demonstrator sites, key roles and responsibilities have been assigned to institutions and actors at the local level, including local governments, communities and companies (see deliverable 3.1). For example, the community interacts with the municipality when it comes to spatial matters, such as building permits or cooperation with adjacent farmers. Other than that, the municipality is not an important stakeholder and they are side-lined from the process as much as possible.[10] Furthermore, Aardehuizen has to engage architectural professionals and continues to rely on the Netherlands Enterprise Agency for exemptions under a so-called "experimentation scheme".[11] This is sometimes experienced as an obstacle as it costs a lot of resources and time. The representative of the demonstrator site anticipates that by the time their experimentation exemption runs out, the national legal framework will have opened up such that they will not need the exemption anymore. Furthermore, the phasing out of the feed-in tariff system[12] has recently been delayed, so this can also have a positive impact on the renewable energy generation. This points to a certain predictability, or at least mid-term consistency of the energy legislation in the Netherlands.

Simultaneously, the community representatives recognized that collaboration and networking with other institutions and actors at multiple levels can be seen as a condition. Interacting with energy companies, architects and others increases the professionality of the local energy system transition project. It has already lead to the development of a network for outreach and replication of ecological building projects – e.g. as part of the Global Ecovillage Network (see deliverable 3.1). Hence, while at times experienced as frustrating, collaboration with other institutions and actors is not only necessary but can also be worthwhile.

An issue that is highly relevant at the moment is the wish of the community to become an energy cooperative to be able sell energy to others or even a DSO, so it can own their own part of the grid. The idea would be that the community could offer a low price for the surplus renewable solar energy, thereby increasing the demand for this kind of energy and stimulate its usage. However, this is legally complicated or even impossible. Nevertheless, the cooperation with the local DSO is reported to be good, apart from the autarky discussions going on.

The Aardehuizen community entertains a future vision with ambitions in the community, regulatory, and networking domains. Its members hope for future rules to accommodate more experimental forms of energy systems. There is also an ambition to develop sustainable building networks by maintaining contacts with architects, contractors, experts, and collaborative municipalities. It becomes apparent that the community members have a positive outlook on and trust in experts to guide them in their ambition towards sustainability. That is not to say, that the future vision could be summarised as 'utopian'. Rather, there is a realist nuance of social learning that develops over time. This came to the forefront in a change of mindset from expecting regulatory developments as soon as possible to considering realistic timeframes taking into account that policy change takes time.

3.4.3 Przywidz, (PL)

In Przywidz, the private sector seems to be the driving force behind the local energy system transition. Yet, representatives of the demonstrator site indicated that a local network with the community is of great importance to gather relevant information for the project and to get people interested and involved (see deliverable 3.1). Furthermore, as in the other two demonstrator sites, key roles and

[10] The specific reasons behind this will be investigated during the SERENE project.

[11] The community is not actively working under/with this exemption as the complete extent of what is legally allowed is unclear to them.

[12] Cf. Schillinger et al. (2022), p.17

responsibilities have been assigned to institutions and actors at the local level, including local governments, communities and companies (see deliverable 3.1). They see local community participation in the project as a condition, in order to enhance trust and eventually achieve a successful transition. One of the ways the Przywidz representatives want to apply to achieve local community participation is to revive a so-called 'energy cluster' – a dormant initiative made up of various local companies. However, it turns out to be difficult to revive the cluster. Therefore, this can be seen as a potential obstacle in achieving a sufficient level of trust in the local (corporate) community. The representatives of the demonstrator site report that they are struggling with a lack of further guidelines and activating policies for the energy clusters by the national government. Besides the notion of 'energy clusters', which was introduced a few years back by the national government as a way of promoting innovation in the energy sector, the idea of 'energy community' is not yet supported by regulations in Poland. There is neither an official definition of the concept, a legal framework, nor assigned responsibility within the government. Although the transposition of the relevant EU directives is anticipated, at the same time, the laws and regulations that do exist are considered to be internally inconsistent with unpredictable outcomes and impacts which do not contribute to building trust in a future consistent legal framework. This leads to uncertainty and potentially fears on part of the stakeholders interested in energy system innovation about future regulation changes. Fortunately, in this case, the energy operator overseeing the Przywidz area is a project partner in SERENE. Therefore, exemptions for certain regulations could be granted. This has already enabled the exploration of mobile energy storage applications that will be installed at different locations to assess the impact of the location of installation on the grid. Another important ongoing regulatory change is the switch from net-metering to net-billing; its impact still needs to be seen, but questions arise as to its role in the incentivisation of solar panel installation. The representatives of the demonstrator site described a relatively strong wait-and-see attitude on behalf of community members regarding how functional technologies will perform before joining an initiative. Furthermore, they mentioned that municipalities are perceived as caretakers; citizens look to the municipality to help them with retrofitting their household energy system. This can be an opportunity to initiate momentum, if the right chord is struck.

Table 6 Institutional issues mentioned explicitly during the key actor interviews.

		Obstacles and conditions	Sites of local energy transitions		
			Hylke & Låsby, Skanderborg (DK)	Aardehuizen & Vriendenerf, Olst (NL)	Przywidz, (PL)
Institutional issues	**Trust, motivation and continuity**	Anticipated (dis-)continuity and (un-)predictability of regulation		X	X
		Influence of regulatory changes on revenue-generating activities (e.g. feed-in tariff systems)		X	X
		(Un-)certainty and (lack of) confidence about roles and responsibilities of different institutions and actors		X	X
		Need for participation of various social groups, collective decision-making and equitable and transparent outcomes			X
		Energy technologies as expert systems requiring laymen’s trust in their functioning		X	
	Energy democracy	(1) Definitions of “renewable energy community” and “citizen energy community” as legal entities are different for EU RED II and IEMD, respectively; (2) challenge is to overcome local legal barriers to exploit opportunities brought by legal framework at EU level	X		X
		Existing regulations prohibit individuals and energy communities to enter the energy market and sell their energy freely	X	X	X
		Presence of coalitions and/or social movements	X	X	
	Ownership	Legal forms for community energy ownership differ from country to country	X	X	
	Locality	Policy priority of local energy system transitions, and responsibilities attributed to local governments and communities, urban societies and policy actors	X	X	X
		Potential inadequacy and non-specificity of current higher-level regulations and policies	X	X	V
		Emotional attachment to place of residence relates to supporting or accepting local energy system transitions		X	
	(Self-) governance	Effective interaction between local energy systems and the surrounding system of institutions and actors, while taking into account different patterns in which this can be organized	X	X	X

		Obstacles and conditions	Sites of local energy transitions		
			Hylke & Låsby, Skanderborg (DK)	Aardehuizen & Vriendenerf, Olst (NL)	Przywidz, (PL)
		Variety of views on whose responsibility it is to deal with the energy transition			X
	Institutional design	Collaboration and networking across institutions and actors *at multiple levels*	X	X	
		Monopoly of classical DSOs on local grids		X	X
		Views of regulations preventing innovative arrangements		X	X
	Roles and responsibilities	Role types for citizens and energy communities in current legal frameworks		X	
	Opportunity structures	Temporal, social, political, cultural, spatial, economic and technological context influences how stakeholders frame local energy systems and the local energy transition	X	X	X
	Discourses and socio-technical imaginaries	Finding the ‘right’ number and range of stakeholder discourses to consider	X	X	
		Stakeholders cannot be assumed to behave rationally or to be open to change in the energy system			X
		Intensity of stakeholder engagement	X		X

4 Potential obstacles and conditions

The obstacles and issues we encountered at the demonstrator sites represent only a share of what the scientific literature reports to be possible. Of course, this relates to each empirical context situated in different political systems, different societies, and different cultural settings. Nonetheless, we will reflect briefly on potential future obstacles and conditions that may occur. For the full list of issues reported in the scientific literature that were not explicitly mentioned as current issues by representatives of SERENE's demo sites, see Table 7.

A considerable number of obstacles and conditions concern legal situations that may still develop once SERENE's local integrated energy systems become further developed. For example, there are a lot of obstacles from the regulations perspective that deal with issues of ownership or privacy. Once the citizen engagement processes gain momentum, more and more questions may arise from the citizens' side as to who owns SERENE's technology, the data, and what rights can be attributed to this ownership. This might lead to the necessity of thinking in terms of bundles of rights. Another aspect, which was already mentioned in Przywidz, but may become more pressing in the other demonstrator sites, too, is that of legislation lagging behind the technological possibilities. This has also been called the 'Collingridge dilemma', which states 'attempting to control a technology is difficult…because during its early stages, when it can be controlled, not enough can be known about its harmful social consequences to warrant controlling its development; but by the time these consequences are apparent, control has become costly and slow' (Collingridge 1980: 19; in: Genus & Sterling 2018: 63). The flipside of this dilemma is the responsibility for scientists (among other in EU projects such as SERENE) to engage in responsible research and innovation.

Similarly, justice-related issues are currently underrepresented in the demonstrator sites. On the backdrop of rising energy prices and the popularity of the notion of energy poverty, it is striking that questions of energy poverty, distributive and procedural justice have not been mentioned as an issue, yet. Once citizens from different social strata will be involved in the project, these issues may quickly take a more prominent role.

Finally, there is a host of issues that may emerge due to time moving on. Bearing in mind our view of socio-technical systems as constituted by three layers, there could be more impactful landscape events; slower, more incremental changes to the way local energy systems are currently governed (i.e. the regime) that figure as gamechangers for existing niches; and new protection or nurturing processes being implemented to propel certain niches forward. Being able to identify such developments relatively quickly is one of the advantages of viewing innovation in socio-technical systems as a process influenced by three layers.

Table 7 List of issues per issue domain that appear in the literature but were not directly mentioned by demo site representatives

		Social science perspective	**Obstacles and conditions**
Technological	**Renewable energy generation**	*Regulations*	Existing regulations are insufficient for ownership and liability for energy generation equipment
			Licensing requirements represent barriers for energy communities to enter the energy market
		Social acceptance	Inclusion of the public in decision-making processes on renewable energy generation
	Energy efficiency	*Regulations*	Minimum energy performance standards represent obstacles in realizing technical innovations
	Storage	*Regulations*	Strict, outdated safety rules for storage devices may prevent installing storage
			New safety issues (e.g. novel battery technologies) for which regulations are required and merely emerging
			Double taxation of storing and use of energy may prevent implementation of storage devices (Not an issue in Aardehuizen at the moment, but it might be an issue if they want to trade with the supplier)
	Local balancing of supply and demand	*Regulations*	Unequal access to consumers' energy consumption data for actors offering energy services
			Smart grids and demand flexibility require clear rules for access to communication networks and data
Socioeconomic	**Paradigm shift**	*Socioeconomic*	New challenges emerge (e.g. congestion, unclear policies, resistance in regions, lagging professionalization)
	Economic incentives	*Socioeconomic*	Large investments have to be made in the beginning, but return on investment follow slowly over time
			High investment threshold for low-income households
	Split incentive problem	*Regulations*	There is absence of rules in dividing costs and benefits, and measures regulating decision-making processes in multi-owner property
			Existing regulations do not address the split incentive problem, specifically current property and tenancy law
	Energy autonomy and security of supply	*Socioeconomic*	Economic aspects related to energy autonomy are life cycle, grid parity, less pressure on grid and job creation
			Prerequisite is that costs and benefits of energy autonomy are shared
	Energy poverty	*Socioeconomic*	Growing number of low-income households that are not able to cover the costs for energy for basic needs
			Additional funds have been or need to made available for insulation and prevention of energy poverty
			The way in which people approach life and deal with energy influences experience of energy poverty
			Energy poverty strongly related to type of housing
	Initial costs and financing	*Regulations*	Competition law favours incumbent actors with more resources in the energy market over new actors, which may eliminate incentives to set up an energy cooperative by citizens in the short term.
		Socioeconomic	Innovations and technologies require high upfront investments, which vary across types of innovations and technologies
Environmen tal	**Environment and climate**	*Regulations*	Whether sources of energy are regarded as renewable is determined through regulations, while this may not necessarily mean that these sources do not worsen climate change or air pollution, or result in other risks (e.g. biofuels, hydrogen, nuclear, wood and pellet stoves, battery systems)
	Emission	*Regulations*	Environmental regulations can become an obstacle for realizing renewable energy generation as all forms still have an impact on air, water and land (see also Environment and climate).

		Social science perspective	Obstacles and conditions
	Waste	*Regulations*	Waste regulations can play a role in choosing technical innovations, e.g. considering that solar panels and batteries lead to forms of (chemical) waste that is difficult to recycle.
Institutional	**Trust, motivation and continuity**	*Social acceptance*	Knowledge, perception and fear influence acceptance of energy technologies
			Moral values influence acceptance of smart meters specifically
	Ownership	*Governance*	Fair models of (co-)ownership need to ensure equitable distribution of benefits amongst institution and actors involved in local energy systems.
	Support schemes and targets	*Governance*	Despite the many institutions and actors involved there appears to be a lack of availability of subsidies, grants and feed-in-tariffs, as well as administrative and technical support
			Local energy system transitions continue to rely heavily on financial support
		Regulations	Support schemes follow their own rules, are based on older liberalized energy market rules and favor incumbent market actors
	(Self-) governance	*Governance*	Need for sufficient models of self-governance and self-organization based on proper organizational principles and policies
			Local energy system transition initiatives remain dependent on external institutions and actors to address barriers
	Institutional design	*Regulations*	Different institutional designs of local energy systems are thinkable, which depends on the energy market and other regulations that may form an obstacle.
	Roles and responsibilities	*Governance*	(1) There needs to be a clear vision and division of roles and responsibilities across the multitude and diversity of institutions and actors; (2) as new institutions and actors enter the governance system, traditional checks and balances regarding accountability are no longer relevant, so accountability mechanisms need to be (re-)designed; (3) governance activities become less transparent as more decision-making nodes become involved.
	Discourses and socio-technical imaginaries	*Societal debates*	Discourses and discursive moves are linked to politics and political decisions

5 Conditions for citizen engagement

Although the readiness of the energy technologies required for smart integrated local energy systems is a fundamental issue, implementing new technologies depends on many other factors in the domain of policies, regulations, user preferences, and culture (cf. Geels 2019, 191). The local energy transitions which SERENE envisions, which are to a certain extent "radical shifts to new kinds of socio-technical systems" (Köhler et al. 2019), need to take into account the visions and interests of various actors involved in those regimes (Sovacool 2019) and look for opportunities to experiment with novel technologies within existing legal and economic frameworks (Van der Waal et al. 2020; Sengers et al. 2019).

Governing this innovation process is thus more complicated than determining the technology readiness level. Rather, it involves intensive engagement with relevant target groups, in many cases leading to co-design of the innovation to be implemented (Voorberg et al. 2015). It also requires inclusive and open-minded behaviour on behalf of the innovation agent, i.e. SERENE's project partners (cf. Pesch 2015). The notion of "responsible research and innovation" (Owen et al. 2013), which captures such a mindset, entails processes that should be:

- Anticipatory: *understanding intended and unintended outcomes* of the innovation through the gathering of 'strategic intelligence' (cf. Kuhlmann and Rip 2018),
- Reflective: "*reflecting on underlying purposes, motivations, and potential impacts*, what is known […] and what is not known; associated uncertainties, risks, areas of ignorance, assumptions, questions, and dilemmas" (Owen et al. 2013, 38),
- Deliberative: including the *visions of wider publics and diverse stakeholders* in the innovation process,
- Responsive: finding *flexibility within research interests* that take up the outcomes of the preceding processes.

For the process of engaging with citizens and communities in SERENE, but also in any other co-evolutionary innovation process, innovation agents can heed the following set of very generic guidelines:

- Begin with an identification of who the relevant target community of the innovation is. This might be straightforward, but it may just as well be a difficult definition issue.
- Carry out activities to understand (a) the context of the community (historical, cultural, socio-political, etc.), and (b) the potential impact of the innovation. While the former is necessary to identify with the community and understand 'where they are coming from', the latter is paramount to address the Collingridge dilemma that was mentioned in section 4. That entails not thinking about potential consequences of the innovation behind the desk, or within the group of SERENE project partners (even the local experts), but asking relevant stakeholders where they see the consequences of the innovation, how they would use the technologies, and how they feel about these.
- Adapt the original innovation plan based on signs received from the community. The motto should be society *with* technology, not society *after* technology.
- Make sure to stay in contact with the community. Taking the notion of 'innovation as a socio-technical change process' seriously, means that citizen engagement cannot be a merely consultative, or 'one-shot' thing.
- Take into account that societal contexts change as the project carries on (cf. landscape events and other changes as described in section 2.1). This may require unforeseeable adaptations along the way and attentiveness on behalf of the innovation agents (in SERENE's case the project partners).

6 Conclusions and outlook

In this deliverable we have reported which obstacles and conditions currently exist in SERENE's three demonstrator sites. Based on a view that technological innovation is always a form of socio-technical change, we discerned four issue domains – technological, socio-economic, environmental, and institutional ones. We cross-checked all of the obstacles and conditions with the scientific literature to see what other obstacles may lay ahead for the demonstrator sites. Finally, we formulated a set of conditions for context-sensitive citizen engagement, which may serve as a guideline for demonstrator sites within SERENE, but also for other socio-technical innovations.

A few observations about the obstacles and conditions prevail. First, given the range and number of issues in the demonstrator sites, the number of issues that occur in all three of them is relatively low. This may point to and confirm that they are all very contextually different. This has consequences for cross-fertilisation and learning processes between the demonstrator sites in general. Any lessons drawn from stimulating and implementing the SERENE innovations must be thoroughly adapted to be usable in other contexts. Second, in the environmental issue domain, the Przywidz demonstrator site representatives have reported the most issues. It was also discussed that this could be used for framing the relevance and importance of innovating the local energy system as promoted by SERENE. Third, across the board we have found that legal and regulatory issues play a role. This relates both to general issues in the institutional domain, such as the potential inadequacy and non-specificity of current higher-level, e.g. EU, regulations and policies, and also to other domains, such as the role of spatial and zoning regulations in the environmental issue domain. Fourth, there are several obstacles and conditions that are reported in the literature that may become relevant in the future. This also holds for some of the issues which were enumerated as currently active, whose extent was not always completely identifiable. This might be, because the demonstrator sites as envisioned for SERENE are still in their start-up phase.[13]

We should also briefly reflect on the framework we used to categorise the issues in the demonstrator sites. As is the case with many analysis frameworks, they do not exactly fit the empirical reality of the demonstrator sites. Depending on the sites one were to study, a framework would require different categories, which is also what we experienced. Thus, such a framework should not be taken as a checklist or a fixed lens. Taken in such a way, a framework only limits the understanding of the complexities of empirical realities. Rather, we take the framework as an adaptable heuristic, open enough to be complemented with new findings. Hence, we rearranged, renamed, or added categories for the purpose of the best understanding of the SERENE demonstrator sites.

Our observations also show that the demonstrator sites are quite different when it comes to the existence of communities. In Aardehuizen there was a strong community right from the start as one of the staple characteristics of that demonstrator site. Inhabitants are united in their quest for the most sustainable lifestyle possible. They are willing to change their practices on top of investing in energy technologies to reduce their climate footprint to a minimum. Przywidz does not yet have a strong community, but given its situation in an urban environment, there is potential to develop a cohesive group of inhabitants with a collective purpose. In the two Danish demonstrator sites, there are different images. One of the sites does not yet have inhabitants due to it being a new construction site. It is for now relatively difficult to define what 'community' means here. The other demonstrator site has not been reported to have significant aspects of cohesion among tenants or community feeling. But this may develop in the course of the project given intensive engagement with the tenants.

[13] As mentioned in section 2.2, we do not deal with business cases and business models explicitly, here. Any issues that came up during the key actor interviews or literature search that relate to economic viability were incorporated. For a more in-depth look at business models, we refer to SERENE deliverable 3.4.

Based on these findings, a few starting points for further activities emerge. First, we need to acquire a deeper understanding of the local situations in each demonstrator site, i.e. the various context dimensions. Second, for each demonstrator site a citizen engagement strategy must be developed and put into action to reap all benefits that can be gained for the development of the local integrated energy systems envisioned in SERENE. For this, the guidelines offered in section 5 can be used. Finally, the findings on obstacles, conditions and citizen engagement provide a solid basis to accompany the demonstrator sites in their respective innovation journeys (cf. Van de Ven 2016; Kuhlmann 2012).

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Appendix: Literature review

Obstacles and conditions in tackling technological issues

Renewable energy generation

Regulations

From the regulatory perspective, it is key to distinguish between domestic renewable energy generation and collectively generated energy (Fouladvand, et.al. 2022). First, regarding domestic generation: ownership of private electricity generation equipment, such as solar panels, is generally possible under current legal frameworks. An individual that produces and consumes energy has been referred to as ‘prosumer’. In local energy, prosumers are mostly citizens who both produce and consume electricity. Parts of the electricity they produce, they use themselves; and the remaining part can be sold to the grid. Current legislation determines that such prosumers who install domestic generation equipment do not fall under the definition of an electricity generator, which requires at least an ‘organizational entity’. Still, there are restrictions to domestic generation in general housing and planning regulations. For instance in Denmark there is a maximum capacity for the installation (6kW). In principle, governments try to avoid visual hindrance, noise and emissions for neighbors; and they might have ethical rules in building regulations regarding the exterior appearance of buildings. For example, some installations, like burning biomass, might be restricted by such rules. In addition to these regulatory conditions for domestic electricity production and distribution, various other legal matters are relevant for prosumers who own technical equipment for electricity generation. For example, related to ownership of property (or agreement with the property owner), liability for damage to or by equipment (which makes insurance companies relevant actors), as well as – for more advanced digital solutions – privacy and cyber security. Hence, tort liability needs to be arranged in a good manner (Wick, 2022). To illustrate, a particularly heavy storm hit the Netherlands in the spring of 2022, resulting in widespread damages to solar panels, which resulted in numerous insurance claims. In countries with widespread insurance for homes, this matter is arguably well-covered; however, in countries where the insurance market is less developed, the question of covering possible damage to energy generation equipment needs to be well-considered. This concerns damage to equipment but damage can also be caused by equipment, for example to people or property. During the same storm, a solar panel hit a bystander and caused death. This triggers the question of liability as well as the possibility to take measures to prevent or compensate for such tragic events. These questions are pertinent, because extreme weather conditions are anticipated in the context of climate change. Besides acts of nature, acts of humankind – such as crimes, vandalism, terrorist attacks or even military operations – are important risk factors in this regard.

Second, regarding collectively generated energy, the regulatory situation is different. While individual prosumers are restricted to selling their surplus electricity to contracted suppliers and are thus not allowed to freely sell their electricity, the situation changes if the ownership of domestic generation is shared with others. In that case, the cooperation between individuals is seen as an organizational entity, which does fall under the definition of an electricity generator. Such renewable energy cooperatives are allowed to be a supplier of generated electricity to its members. Still, these organizational entities are not allowed to sell electricity to other actors or individuals beyond its members, limiting their role on the energy market. An energy community interacts with other legal actors: private parties when it signs contracts for the sale and supply of electricity and when it purchases or leases equipment (e.g., solar) panels), but it also interacts with public bodies such as regulators, municipalities and tax authorities. If an energy community is involved in generation, sale and supply of electricity, the nature of these activities require at least some level of regulation. Finally, for those entities that wish to enter the energy market to supply electricity to consumers beyond its own members, a licensing regime is in place. Licensing requirements are to ensure that suppliers of electricity can ensure safe and stable supply and can comply with universal service obligations. Universal service obligations mean that the provider should be able to supply any client, regardless of the location and that they meet minimum criteria with respect to finances and administration. In practice, these requirements can pose an important barrier for a community wishing to enter the energy market as an electricity supplier. Universal service requirements are difficult to comply with, unless the community establishes partnerships in various areas in a country so that it can meet energy demand anywhere. An alternative is for the community itself to become a partner with an established player on the energy market who has a license.

Social acceptance

From the social acceptance perspective as well, various obstacles and conditions have been found in relation to renewable energy generation. This mostly relates to renewable energy generation requiring decentralized infrastructures. Several studies have been conducted on the individual or community level acceptance of such infrastructures. A group of studies have found a strong opposition at the community level towards renewable energy infrastructures such as wind farms and related technologies such as high voltage power lines (Devine-Wright & Batel, 2017). This type of behaviour is also described as NIMBYism (Not In My Back Yard; (Dear, 1992)), which distinctively characterizes the local opposition towards energy infrastructures that are considered as loud, unseemly, and/or unattractive. The concept has been criticized for providing justification for unjust self-centred behaviour towards sustainable energy transitions (Bell, Gray, Haggett, & Swaffield, 2013; Mcclymont & O'hare, 2008; Wolsink, 2006). However, some scholars claim that NIMBY is not a representation of self-centred behaviour, but instead, they argue that it should be considered as an expression of frustration that the public is left out in the decision-making processes (Schreurs & Ohlhorst, 2015). Furthermore, NIMBY can also be perceived as a community level concern for unnecessary development. Van der Horst (2007) found that NIMBYism is more prevalent among communities that have their identities strongly associated with rural sceneries. Other studies discussed the positive effects of NIMBYism, which is the initiation of community learning processes and community communication (Hager, 2017), which allows communities to be more independent and develop the abilities to negotiate their political resources (Batel & Devine-Wright, 2020).

Considering the complex relationship between social acceptance – sometimes expressed through protests and other forms of community action such as NIMBYism – and energy transitions, the concept social acceptance needs to be broken down. Social acceptance is a multilevel social construct that have individual or demographic associations as well as relationships with structures and forms of local and national governance. In the next sections throughout this report, different forms of social acceptance towards energy transitions are discussed. Therewith, this report contributes to a theoretical understanding of the relationship between social acceptance and energy transitions.

Multi-carrier energy system (heat-power)

Multi-carrier energy systems play a role in the SERENE demonstrators. Such systems are characterized by strong coordination across multiple energy vectors. Some obstacles and conditions have been found from the regulatory perspective.

Policies and regulations on renewables focus primarily on power generation, while adjusted regulation efforts in heating and cooling and the transport sectors are lagging behind (European Commission [EC], 2020). More specifically, there is a lack of regulations that take a system approach to fully integrate energy sectors, incorporate supporting infrastructures, include measures for balancing supply and demand, and take advantage of synergies between power and heat with energy efficiency and increased access to electricity. With the EU strategy for energy system integration (EC, 2020), the EU seeks to stimulate energy system integration and coordinated planning and operation of the energy system 'as a whole', across multiple energy carriers, infrastructures, and consumption sectors. However, at this moment in time, there are still regulatory obstacles due to vertical energy carrier rules when it comes to creating low carbon local energy systems (Luteijn-Nava Guerrero, 2022). For example, an energy consumer who wants to use a heat pump instead of natural gas for heating might be confronted with regulatory obstacles and high fees related to disconnecting from the gas grid. Especially supplying heat pumps to buildings that fall under monumental heritage regulations is difficult.

Intermittency of local RES generation and demand response

Intermittency of local renewable energy generation and demand response relates to the fact that renewable energy generation varies with time and weather, often not in parallel with consumer demand and behaviour. Associated obstacles and conditions have been found only from the regulatory perspective.

Electricity supply must be equal to electricity demand at all times and, if not, local energy systems risk breaking down. Technical functionalities of smart grids extend the distribution system beyond the electricity grid by adding communication networks for data exchanges, which make it possible to manage flexibility technologies. These functionalities have the potential to cope with the intermittency of renewables. However, regulations on data management might complicate the implementation of such a demand-response system. This legislation is evolving but regulatory progress and policy support need to advance more rapidly (International Energy Agency [IEA], 2021).

Energy efficiency

Energy efficiency refers to energy efficiency still not being common practice in local communities, despite improvements that have been made at the household level when it comes to appliances. Several obstacles and conditions have been reviewed related to this from the regulatory and social acceptance perspectives.

Regulations

Energy efficiency also plays a role in the low carbon local energy systems that are strived for in the SERENE demonstrators. Here, regulations on the built environment (e.g., related to insulation standards) or regulations that prescribe energy performance standards come into play. Such prescriptive standards (e.g., requiring that a particular feature or device is installed or not), minimum energy performance standards (MEPs) or class-average standards can become an obstacle in realizing technical innovations in local energy system transitions (de Vries and Verhagen, 2016).

Social acceptance

One of the ways to improve energy efficiency is for users to shift their energy usage to preferred time periods – usually of lower energy demand. However, despite the importance of energy shifts and energy efficiency, Darby (2010) noted that demand shifting by users has been rather difficult to achieve. For example, Kobus, Klaassen, Mugge, and Schoormans (2015) found that only four users switched their demands out of 38. Other scholars have found that digitalized energy technologies, including smart meters, can result in energy savings and a reduction in energy (Nyborg & Røpke, 2013). However, the term 'energy saving' itself is rather vague and has become synonymous with the introduction of smart energy technologies (van Mierlo, 2019).

Storage

Storage is seen as a key part of future energy systems, as it can deal with the fluctuations of renewable energy generation and help balance supply and demand. Similar to the previous section, several obstacles and conditions have been identified from two perspectives: regulations and social acceptance.

Regulations

As stated, storing energy provides a way to balance energy supply and demand; in times of low demand and/or high supply, energy is stored to be consumed later when there is high demand and/or low supply. A regulatory obstacle related to storage is double taxation. Under most legislation, if one stores energy to sell it later, one might have to pay tax twice; once for storage and once for usage. This results in the possibility of storage becoming unattractive. In Poland recently amended legislation[14] has removed double taxation and double payment for energy transfer. Also, it distinguishes 2 categories of

[14] http://eli.sejm.gov.pl/eli/DU/2021/1093/ogl.

storage (below 50kW and above 50kW) and generally makes energy storage more interesting for investors. Another obstacle relates to safety. Lithium batteries, which are the industry standard for storage devices, that are used in local energy systems have to comply with safety regulations. The Batteries Directive (Directive 2006/66/EC), last amended in 2018, is the main legal act regulating batteries at EU level. This directive applies to nearly all types of batteries, regardless of their chemical nature, size or design, and classifies them according to their use. The EU is currently working on a new regulatory framework for batteries to set sustainability requirements, but at the moment this legislation forms an obstacle for installing storage devices as part of local energy systems.

Social acceptance

Storage is a technology that requires social acceptance. This can be linked to literature on the social acceptance of electric vehicles (EV), because EVs can potentially be used as external storage for individual households without incurring a massive cost (Bühler, Cocron, Neumann, Franke, & Krems, 2014).[15] The cost is particularly important in understanding storage and EV purchases (van Heuveln et al., 2021). A study conducted in Germany found that EVs are generally well-accepted and the public has a positive opinion towards EVs (Bühler et al., 2014). Although another study showed that in the Netherlands, the decision to purchase EVs is simultaneously influenced by various social, infrastructural, and technological factors, such as trip planning, infrastructural demands, car sharing, and battery degradation (van Heuveln et al., 2021). If storage is supposed to become part of a local energy system, understanding such preferences of individuals and the factors that influence these is of key importance.

Local balancing of supply and demand

The importance of balancing supply and demand due to intermittency of renewables has been explained already in the previous sections. Related hereto, there are several obstacles and conditions from the regulatory and social acceptance perspectives.

Regulations

While beneficial, smart grids and demand flexibility make the distribution of energy in new low carbon, local systems increasingly complex. This requires clear rules for access to communication networks and data that is non-discriminatory for new system users. This follows from the principle of liberalized energy markets or independent network operations, through which any potential producer or consumer is allowed to participate in the market. However, these new users need access for operating in the market and getting equal access to the market compared to existing actors who traditionally operate on the market. These actors have a competitive market advantage. As a consequence, the regulatory obstacle emerges that rules are needed to deal with data on consumers' energy consumption and making it available for other actors offering energy services (Diestelmeier, 2021; EC, 2011). There are also activities of a different nature that are applied by local energy communities to balance supply and demand: for example, grid offloading through adjusted behaviour (i.e., receiving compensation to alter their energy consumption in a way that facilitates grid balancing) or installing a EV charging park. Whichever market or non-market behaviour energy cooperatives apply, the regulations need to provide for this.

Social acceptance

A smart meter is one of the key technologies energy transitions rely on because it can track household level energy use (Lee & Hess, 2021). Such data is invaluable in grid and load management, as well as energy efficiency and procuring renewable energy. Therefore, many countries have made the installation of smart meters mandatory, without an option to opt-out unless there are medical conflicts

[15] This is closely related to vehicle-to-grid issues.

(Lee & Hess, 2021). Despite the importance of smart meters in energy transition processes, the public responses have been somewhat varying (Hess, 2014; Hess & Coley, 2014).

The main concerns for smart meters have been privacy and security. Because it tracks energy use of a house regularly and frequently (in some countries as often as 15-30 minutes), the data can be used to discern whether someone is in the house, and at what time, as well as their socio-economic status, dwelling, appliance usage, and other personally identifying information (Buchmann, 2017; Lee & Hess, 2021; McDaniel & McLaughlin, 2009). Consequently, privacy and security have been a key societal challenge in smart meter acceptance and many governments attempted to address privacy and security though guidance policy, anonymization, and data decentralization (Hess, 2014; Lee & Hess, 2021).

Another concern regarding smart meters is the perceived health problems that derive from smart meter installations. Smart meters emit non-ionizing radiation (NIR), and the potential health consequences of non-thermal effects of NIR has been a point of controversy. Many grassroot groups and scientific advisory groups have recognized the potential dangers for low-dose microwaves from mobile phones – the same non-thermal effects of NIR from smart meters (Hess, 2014; Hess & Coley, 2014; International Agency for Research on Cancer [IARC], 2011). However, government organizations and industry actors have been found to not recognize the health effects of non-thermal NIR (Hess & Coley, 2014).

These societal challenges and public concerns have led to discussions on the regulatory frameworks of smart meters and having opt-out policies available (Lee & Hess, 2021) and on health oriented precautionary politics of smart meters and other energy technologies (Hess & Coley, 2014).

Local flexibility and impact on larger energy system

Local flexibility and impact on the larger energy system includes technologies and methods such as co-generation, fuel cell batteries, heat pumps, electric vehicles and community energy storage as well as demand response. Various obstacles and conditions have been found from the regulatory and social acceptance perspective.

Regulations

The EU regulation and directive on the internal market for electricity (EU 2019/943 and EU 2019/944) focus also on flexibility and how it can affect the transmission and distribution. From a regulatory perspective, trade barriers; differences in tax and pricing policies, in norms and standards and environmental and safety regulations have to be taken away proper functioning to ensure a functioning local flexibility market with fair market access and a high level consumer protection.

Social acceptance

Another way to facilitate local flexibility is through transactive energy. Although there is still some dispute over the definition of transactive energy (Chen & Liu, 2017), the concept is understood as *"a system of economic and control mechanisms that allows the dynamic balance of supply and demand across the entire electrical infrastructure using value as a key operational parameter"* (The GridWise Architecture Council, 2015, p. 11). Another helpful characterization of transactive energy is that of Chen and Liu (2017), who describe seven central features of transactive energy, which are:

> distributed intelligent devices are controlled in real time; these devices are 'controlled' based on economic incentives rather than centralized commands; these devices exchange information and make transactions in a decentralized way to ensure scalability; these devices are automated to enable real-time transactions and control; these devices are controlled by their owners rather than power companies; transactive energy provides joint market and control functionality; and both supply and demand side resources are coordinated. (p. 14)

The main problem of energy technologies that are very advanced and require skills of consumers such as using smart thermostats and water heaters as well as other house management systems is consumers' insufficient experience. In addition to "generation of systemic risk" and "lack of economic feasibility", Lee, Hess, and Neema (2020) found that users were generally not ready to use smart and connected systems. Transactive energy experiments consistently showed a strong need for education and greater customer service, a problem with smart meter compatibility, and a high participant dropout rate. Overall, the findings of this study show that users may not be ready to accept energy technologies that they may not fully comprehend.

Obstacles and conditions in tackling socioeconomic issues

Paradigm shift through community engagement

Paradigm shift through community engagement broadly refers to the growing importance of more deliberative and inclusive participation of communities and individuals in the energy production process. Various obstacles and conditions have been found from the socioeconomic, regulatory, urban planning and social acceptance perspectives.

Socioeconomic

In various countries, local energy system transition initiatives are one of the means to achieve climate ambitions. Also in the Netherlands, local initiatives are expected to contribute to the high ambitions in the Climate Agreement. Accordingly, research by Koens (2019) and Natuur en Milieu Overijssel (NMO) (2020) show a growth in the number of local initiatives in the provinces of Overijssel and Groningen (Netherlands). A combination of three factors explains the increased involvement of society in energy production and supply: the increase of (1) possibilities to generate energy locally, (2) attention for sustainability and (3) attention for local production. On the one hand, NMO (2020) notes that there is more cooperation between such local initiatives, joint implementation of projects, and substantive and financial support from an umbrella organization (Dutch: Nieuwe Energy Overijssel). On the other hand, new problems emerge, including congestion of the grid, unclear public policy, resistance in the region, difficulty finding suitable roofs for solar panels and lagging professionalization (NMO, 2020).

Moreover, research by Motivaction (2018) shows that a large minority (40%) of the Dutch population is prepared to be guided, to some extent, by social goals when using electricity. The conditions are often that this should not be at the expense of comfort, nor should it cost much effort and money. Measures should be aimed at influencing the electricity consumption from the outside in such a way that the consumer hardly notices it, for example when charging an electric car or when starting the heat pump (prematurely) seems to be acceptable, especially when it is accompanied by a financial incentive (Motivaction, 2018). This also relates to community engagement, which in turn is dependent on the acceptance of the energy system. Community engagement and acceptance can lead to behavioural change in energy usage. Having regular meetings with(in) communities to discuss energy consumption can lead to more careful behaviour when dealing with energy (TKI Urban Energy, 2020).

Regulations

The 'Clean energy for all Europeans' package from the European Commission, published in 2019, put consumers at the centre of the clean energy transition and created new rules to enable the active participation of consumers. Therewith, participation from all the key energy stakeholders – such as utilities, municipalities, cooperatives, property owners, industry and citizens – became a key aspect of the transition towards a low carbon, citizen-centered local energy system. More specifically, the Directive on common rules for the internal electricity market ((EU) 2019/944) includes new rules that enable active consumer participation, individually or through citizen energy communities, in all markets, either by generating, consuming, sharing or selling electricity, or by providing flexibility services through demand-response and storage. The directive aims to improve the uptake of energy communities and make it easier for citizens to integrate efficiently in the electricity system, as active participants However, general regulation for participation processes in local energy decisions can become an obstacle for the realization of local energy system transitions, due to the complicated nature and duration of decision-making processes. For instance, participation in regional energy planning processes that decide about the type and capacity of renewable energy generation. This can become a regulatory obstacle for real citizen engagement and instead result in unrepresentative engagement of a small group of citizens. More specifically, the quality of democracy will be affected if decisions on investments are taken by a relatively small group in the community, the energy community, and not by a representative local council (Chávez Hernández, 2021).

Urban planning

From a spatial governance perspective, local sustainable energy communities are part of a larger trend in post-industrial socio-spatial systems towards increased presence and significance (for the planning and management of a place) of bottom-up dynamics: decentralization, self-organization, self-determination, and renegotiation of the use and purpose of urban space. However, this trend also means contestations and incompatibilities with the overly top-down view of planning institutions with respect to the spatial allocation of resources and regulation of flows and activities. Oftentimes the dissonance between top-down and bottom-up determination and use of the lived environment inhibits creative, out-of-the-box solutions for the sustainable use of resources and resilience of communities. Dissonances of this particular nature are also found in the domain of local sustainable energy communities—essentially hindering the realization of both the sustainable and the community components. Commoning opportunities have indeed emerged in the literature, as frameworks to approach as well as facilitate bottom-up and adaptive energy governance; see, for instance, Petrescu, Petcou, and Baibarac (2016) for a particularly illuminating example of integrating energy commons into a larger superset of neighbourhood commons.

A fundamental incompatibility of the current position of the concept of energy in contemporary societies is the setup of the electricity production and consumption system with economic objectives. Electricity is realized as a private good, whereas the production, exchange, and consumption system is centralized to support mass consumption (Giotitsas, Nardelli, Kostakis, & Narayanan, 2020), which leads among others to unsustainable resource patterns, socioeconomic inequality, and hinders the very idea of a local sustainable energy community. Giotitsas et al. (2020) take the aforementioned as their point of departure, suggesting that a way forward is to establish a commons-based political economy that is facilitated by peer-to-peer (P2P) electricity sharing, coupled with subsidies to maintain the infrastructure and its re-arrangement into micro-grids. Montakhabi et al. (2021) do note, however, that any attempt to radically alter the existing energy use patterns over space and time quickly meets the technical limitations of the current energy distribution infrastructure, which is designed with relatively even spatiotemporal loads in mind.

Nevertheless, the major implication of such an approach is the fact that no-one will own the energy asset. From a political economy standpoint, Giotitsas et al. (2020) make it clear that it will rid the electricity system from the dead-ends of neoclassical market-based approaches, whereas from the viewpoint of urban planning this is likely to lead to a symbiosis between civil society and government. The importance of such a symbiosis has been evidenced elsewhere in the urban commons literature, as even the most successful commons experiments have been seen as temporary grassroot nuisances by top-down institutions and have met the strong resistance of the local governments (See, e.g., Petrescu et al., 2016). The establishment of a micro-grid based P2P energy commons can be facilitated through a commons-oriented energy internet that connects multiple energy communities on the basis of an I/O of energy request packets (Giotitsas et al., 2020). In such energy internet, energy is quantized into limited duration packages and an energy server optimizes needs among micro-grids vs profits, thereby making it possible that electricity use, supply, and the attached costs and benefits are distributed across users (Giotitsas et al., 2020).

While introducing the smart city paradigm as a means to overcome fundamental market-driven obstacles and facilitate the proliferation of local energy communities, Montakhabi et al. (2021) note that over-emphasizing the normative, data-driven flavour of smart city approaches also introduces the risk of side-tracking the role of people (and their values), as data speaks instead of the citizens. At the same time, they note that a fundamental problem with increasingly local renewable energy systems (RES) at local scales is that the presence of electricity surpluses and storage capabilities increases the probability of self-consumption and diversification of energy use destinations; for instance, the buying of an electric vehicle by a household with energy surplus due to their RES. Montakhabi et al. (2021) ultimately argue that a P2P electricity concept has to be based on interaction between community members and not of data in order to prevent the backlashes of self-sufficient but also uncoordinated energy islands. To achieve this, they highlight the factors of user involvement and customer ownership in P2P trading or sharing, and they establish a network of actors and values as a guide that aims to reduce uncertainty through an ecosystem approach (Table A.1).

Table A.1 *Value generated by P2P electricity trading*

Levels of Value Generation	Type of Value
End customer value	Autarky, self-sufficiency, or independence of energy supply
	Autonomy
	Green energy
	Lower electricity costs
	Positive attitude to regionality
	Sense of community identity
	Intangible returns (built upon the notion of togetherness, friendship, love, solidarity, and different ways of bonding with others)
	Responsibility to future generation
	Sustainable lifestyle
	Desire for greater agency (active participation) in the energy transition
	Social comparison
	Perceived importance of shared generation and consumption and easy implementation
Business value	Make electricity less expensive, including making renewable energy more profitable and “supporting new and better mechanisms for return-on-investment beyond government subsidies”
Collaborative value	Electricity grid balancing and stability
	Transmission losses are minimized, making local energy communities
Socio-Environmental value	More robust against failures of the electricity grid
	More socially equitable energy system
	Cleaner energy system
	Involves sharing electricity, underlining that not only monetary but also ideological reasons motivated participation
	Intangible returns are built upon the notion of togetherness, friendship, love, solidarity, and

	different ways of bonding with others
	Environmental benefits

Note. Adapted from ‘‘An Ecosystem View of Peer-to-peer Electricity Trading: Scenario Building by Business Model Matrix to Identify New Roles,’’ by M. Montakhabi, F. Zobiri, S. van der Graaf, G. Deconinck, D. Orlando, P. Ballon, and M. A. Mustafa, 2021, *Energies, 14*(15), p. 4438.

Based on a number of scenarios, Montakhabi et al. (2021) conclude that the main lesson from an ecosystem approach to P2P electricity markets is the emerging importance of two new actor roles: brokers and representatives with the capacity to reconfigure existing network structures towards more effective and collaborative setups. However, the authors also note that these roles need to also be considered in relation to data privacy regulations per GDPR so that that household-identifying information that is needed for the functioning of the P2P system and through the emerging new actor roles is utilized in a way that does not reveal the identity of the households.

Continuing on the themes of user involvement and customer ownership, from an energy commons perspective the two biggest obstacles are the concentration of the sources of energy at a few geographical locations, and the private control of the distribution of energy by a few companies (Hoeschele, 2018). While RES and their structural incorporation in local energy communities is a way forward, localization alone cannot ensure that the benefits are shared across sectors and the local population, leading to problems with active support and uptake (Hoeschele, 2018). Privatization of RES infrastructure is a worrying trend, with the assumed market efficiency proven to be an erroneous hypothesis; there is a necessity to systemically re-think energy as a common urban resource which follows a number of enabling factors (Hoeschele, 2018). Firstly, a shared energy infrastructure has to be in place, where people both own and operate the distributed renewable energy facilities, as well as distribute themselves demanded energy, which echoes both Giotitsas et al. (2020) and Montakhabi et al. (2021) views on P2P human-centered networks. Secondly, community ownership of and responsibility for off-site RES such as wind turbines or large solar arrays has to be in place, in addition to the small-scale RES that are privately owned at the household level. Thirdly, ownership of distribution systems by cooperatives, municipalities, or trusts can avoid monopolization tendencies. However, this depends on the geographical setting as cooperatives seem to work better in rural areas, whereas municipal or trust models appear to work better in urban areas. Fourthly, distributional fairness is an important factor. It must be ensured that the profits coming from the production of energy infrastructure (generation and distribution) are shared fairly inside the company’s employees as well as with those who install the systems. This can be best facilitated when employees own the companies themselves, as well as when communities ensure that the procured services come from fair companies.

Moreover, a further number of urban policy and urban planning practices have been reported as enabling factors by Hoeschele (2018) for a number of cases. With respect to public choice, the case of Hamburg (See https://www.energieportal-hamburg.de) shows citizen movements can provide the necessary accountability by “reclaiming” the power grid and using digital tools to monitor the sustainability profile of municipal operations, which, although lacking legal power, it nevertheless creates a mechanism that influences the choice of elected municipal officials. Similarly, the case of Auckland (See https://www.entrustnz.co.nz) shows that public oversight can be combined with profit sharing through the establishment of a citizen-owned trust. With respect to common financing of RES investments and common sharing of the yielded benefits, a number of cases are reported. The case of Danish wind farms (Douthwaite, 1998) shows that the pooling of funds through a cooperative can address both the underinvestment for RES by the private sector and the lack of funds at the household level in cases where the social benefits of large-scale RES are large but are not reflected in the private cost-benefit assessments. A similar case in Washington DC (Johnson, 2014) shows that a common purchasing strategy by the community yields significant reductions in the utility bills of the member organizations. Similarly, in Ontario, the investment by residents into solar bonds provide grassroot subsidy for increasing RES investments while at the same time achieve a balanced distribution of the benefits (See https://solarbonds.ca), whereas another promising strategy from across the US is the fair distribution of RES installation profits among workers via a cooperative (See https://www.namastesolar.com).

Social acceptance

Market structures and regulatory framework have been central opportunity structures that affect energy transitions and decentralization. Their importance is particularly shown in a study by Hess and Lee (2020). The study focused on two different energy decentralization programs, community solar and community choice aggregation (CCA) in New York and California. CCA was successful in California, but community solar failed and the reverse was the case for New York where community solar was successful, but CCA was unsuccessful. Other studies have shown the importance of market structures, policy decisions and outcomes (Brisbois, 2019; Johnstone & Kivimaa, 2018), and other political discourses (Brisbois, 2019) in the development of energy transitions.

Economic incentives

The rising costs people must pay for energy has led to an increase of community initiatives on energy in developed countries. Especially when the benefits are remunerated (i.e., the right economic incentives are in place), communities and citizens are increasingly willing to invest in local energy systems. Although it is important to note that this is highly case specific, for example when energy poverty is involved (see Section 4.2.5). Related to economic incentives, obstacles and conditions have been found from the socioeconomic and regulatory perspectives.

Socioeconomic

The origin of many energy communities in Northern Europe is the pursuit of a cheap and reliable energy supply. The prospect of being able to rely on cheap energy now and in the future is an important economic incentive for the emergence of energy communities. In order to benefit from the cheaper energy of energy communities, many negative (economic) incentives must be overcome. The investments have to be made in the initial period and the returns gradually follow over time. The condition for being able to invest is particularly disadvantageous for people with low incomes. Furthermore, it is often difficult and expensive to find joint space for joint energy activities and people remain dependent on a distribution network in the hands of a third party (Koirala et al., 2016; Reis, Gonçalves, Lopes, & Antunes, 2021).

A solution for excessive investment costs for the participants can be found in the involvement of a third party and Public Purchasing Agreements (PPAs) (Reis et al., 2021). The space problem can be solved by opting for collective solutions for generation and storage. To get rid of the dependence on a third party for distribution, the choice can be made, depending on how it is legally arranged, for the option 'local energy market'. In the Netherlands, until recently (September 2021), local trade was only possible under the experimental status of the Electricity and Gas Act (Rijksdienst voor Ondernemend Nederland [RVO], 2021).

Reis et al. (2021) also point out the importance of the non-economic outcomes: ‘the collective behavioural change, the environmental awareness and the community cohesiveness are also transversally promoted by all the business models. When developed by local entities, energy community business models promote local job creation, support transformation processes and technological innovation (Reis et al., 2021). It is important to note that behaviour is the result of the sum of stimuli.

In advanced energy communities, Reis et al. (2021) distinguish between the consumer flexibility aggregation and the E-mobility cooperatives, whereas Koirala (2017) and Koirala et al. (2016) talk about Integrated Community Energy Systems, which shows that there are more opportunities to obtain added value. The electricity efficiency of these systems can be increased by using Energy Service Companies (ESCo) and aggregators. ESCos are third party organizations that can use ICT to ensure that electricity consumption within an entity is properly coordinated, so that peaks can be attenuated and/or optimal use can be made of self-generated power. Aggregators are also supporting third party companies. These firms aggregate supply and demand of different firms and organizations. Aggregators act in the potential of being able to draw steam for a certain period of time or feed it into the grid. Grid operators pay a reward for this in connection with balancing. A portion of this reward can be returned to ESCos and the customers for whom the ESCo works.

It has so far only been discussed in general and broad terms why one should join an energy community. It is important to look beyond and to other factors which make one join in a locally integrated energy system. It is important to be reminded of the fact that an integrated local system also means that your energy consumption is controlled. Steering energy consumption can be done automatically from outside or otherwise through (price) incentives that lead to an adjustment of consumption behaviour. Then the question arises what conditions are necessary to choose voluntarily for a certain system. The follow up question is what the incentive effect is within the system.

Motivaction (2018) has conducted research into the willingness to opt for a certain system. In that study, Motivaction divided the population in separate groups according to lifestyle. Lifestyle influences the willingness to choose a certain system. A distinction can be made between people wishing a proportional compensation when participating and there is a group in Dutch society that wants to make limited adjustments for social purposes without wanting direct compensation. Systems in which a heat pump or charging EVs are controlled from outside in such a way that the customer hardly notices it, combined with a small financial compensation, seems promising. When it comes to adjustments within the system, it is noticeable that price incentives and other incentives (information provided in a convenient way) have little effect. Especially when it comes to recreational use of electricity, the elasticity for incentives is very low.

Regulations

In the past the technological setting of energy was also reflected in the tariff (or pricing) structures for supply and transport (network) (Kapitonov and Patapas, 2021) Typically, supply tariffs entail a fixed charge per kilowatt hour, with potential variations between day and night-time usage, and with respect to the volume of electricity. In the new low carbon system this becomes much more complicated. There are new developments like negative energy prices and flexible energy prices. More actors get involved in the production, trading, marketing, transmission and supply of energy and particularly electricity. Some of these activities might be subsidized or influence prices. A regulatory obstacle is if subsidies lead to perverse influences on the local energy system which cannot be taken away because of the regulation.

Willingness to pay

Koirala et al. (2016) refer to the willingness to pay more for electricity if it is local and/or sustainable (or produced in a socially responsible manner). Obstacles and conditions related to this have been found from the socioeconomic perspective. First, it must be stated that this is very much dependent on the situation and individual in question. This brings up the question to what extent people wish to pay extra for the local aspect within local sustainable energy supply. In the Netherlands and Denmark, some people voluntarily pay extra for green electricity. Although it is key to remember that the stimulus in many local projects is to pay less for energy. This means it is difficult to say if there is a special willingness to pay for local energy.

Research in the United States shows that there is a willingness to pay a higher price for houses equipped with renewable energy (Knapp, O'Shaughnessy, Heeter, Mills, & DeCicco, 2020). A German study even revealed the factors that may influence the choice of green energy: a person's exclusion from renewable energy sources. Besides this, (other) financial incentives such as subsidies matter (Danne, Meier-Shoff, & Musshoff, 2021). Karasmanaki (2021) found that the willingness to pay levels of citizens in the EU are mostly influenced by the environment and demographics by ages (in particular: gender, education level and income status) (Karasmanaki, 2021). Moreover, Mamica (2021) found in a study based on the situation in Krakow that the type of house is important. The willingness to pay of residents in detached houses or terraced houses was twice as high compared to residents of apartment buildings or tenements (Mamica, 2021).

Split incentive problem

The split incentive problem broadly relates to the fact that different stakeholders are involved in local energy systems with perhaps different incentives or ideas on how benefits should be shared across stakeholders; how to make sure that "those who are not involved in the costs do not rip the resulting benefits" (Koirala et al., 2016, p. 736)? Tackling this issue involves obstacles and conditions that are reflected upon from two perspectives: socioeconomic and regulatory.

Socioeconomic

The problem of split incentives mostly relates to types of housing. In the situation that houses are rented instead of being owned by the occupant, the responsibility for energy consumption is split between two parties: the tenant and the property owner. This division of responsibility could lead to sub-optimal behaviour because the benefits and burdens for the individual parties are not in balance. This problem can be seen as split incentives. The question arises what can be done about this problem.

Aydin, Eichhotlz, and Holtermans (2019) distinguish two types of split incentives: (1) overconsumption if the fixed amount to be paid monthly in rent includes an allowance for energy consumption, or (2) underinvesting in energy savings by homeowners due to the fact that they do not immediately reap the benefits. Underinvestment is expected to lead to higher energy expenditure. Aydin et al. (2019) gained these insights by first conducting a literature study and then a large-scale study in the Netherlands involving three million houses. Based on a literature study, Aydin et al. (2019) conclude that energy-inclusive rental contracts lead to more energy consumption than otherwise would have been the case. However, since the available studies show different results, it is difficult to provide a general picture. Yet, the overall picture seems to show limited effects. A striking statement is that homeowners appreciate energy-intensive contracts. Tenants would be better off on average compared to exclusive contracts (Aydin et al., 2019).

A mixed picture emerges from the literature review (Aydin et al., 2019). A German study shows higher energy expenditure for tenants and an English study initially shows the opposite. However, if the English study corrects for the type of home, the differences seem to disappear. A study in Austria shows that occupant-owners spend more money on energy. All studies show that type of housing and family composition are very important factors. These factors are so decisive that it is difficult to make accurate statements on the basis of the literature study. Other studies into the real estate market, cited by Aydin et al. (2019), show that the market appreciates sustainable houses, which is an incentive for property owners to make investments. Specifically, the Dutch market for rental houses is regulated in such a way that insulation measures give a property owner the right to increase the rent (extra) (Rijksoverheid, n.d.).

The following quote from Dyson, Chen, and Samiullah's (2010) study is telling:

> The 2009 study also asked these property managers/owners why they installed energy efficient equipment in their tenant units even though their tenants pay their own energy bills. Their most common response, by far, was that they thought that if their tenants could save money on energy costs, they would have more money left over for rent. Other reasons included improving tenant satisfaction and increasing property values by replacing old lighting fixtures. (p. 64)

The large-scale study in the Netherlands shows no split incentive with regard to investing in energy-saving measures. This means there is no under-investment. The article does not distinguish between houses that are owned by housing associations and houses that are not. Housing associations in the Netherlands own two thirds of all rental properties. It is known that housing associations have committed themselves to agreements with governments and residents' organizations to make houses more sustainable (Aedes, 2021).

Regulations

A regulatory obstacle for creating innovations in the local energy system is that there might be no regulation to address the split incentive problem. The split incentive problem particularly concerns the lack of appropriate incentives to implement energy efficiency measures, though it could be extended to measures such as installing solar panels on tenants' roofs or alternative forms of heating for tenants' buildings. The basic idea of the split incentive obstacle is that it discourages multifamily property managers and owners from improving the energy efficiency of their tenant units. The assumption underlying this obstacle is that, even though property managers and owners are responsible for facility improvements because they usually do not pay energy bills for the tenant spaces, they have no direct financial incentive to install more expensive energy-efficient measures. This obstacle is caused by principles in property and tenancy law, and the absence of rules for dividing costs and benefits between them, including national rules and measures regulating decision-making processes in multi-owner property (Castellazzi, Bertoldi, & Economidou, 2018).

Energy poverty

The next issue here addressed is energy poverty, which is derived from the original categorization of issues by Koirala et al. (2016). There is a global definition of energy poverty, referring to "end-users lacking access to modern energy services" (Koirala et al., 2016, p. 736). In the context of advanced economies, it specifically refers to the growing number of low-income households that are not able to cover the costs of energy for their basic needs. Obstacles and conditions in tackling energy poverty are in this section described from the socioeconomic perspective.

In the light of both the impending energy transition and the energy crisis in autumn and winter of 2021/2022 as a result of international tensions, energy poverty received increasing attention in a country such as the Netherlands. In response to the sharp rise in energy prices, the Dutch government lowered the energy tax last year (2021), made additional funds available for insulation, and supported municipalities in the prevention of energy poverty. Whilst in preceding years energy poverty has already been an important issue in many places in the Western world. There are different definitions of energy poverty. Churchill and Smyth (2021) base their definition on the families who are unable to heat their homes to the desired temperature. For a study in the Netherlands, TNO uses a definition consisting of various elements, in which both the income situation and the condition of the house play a role.

Churchill and Smyth's research highlight two sides to the energy poverty issue. On the one hand, the seriousness of the situation is discussed in both a quantitative and qualitative way. Quantitatively, one should think of the high percentages of households that experience energy poverty in the United States and in Wales, Scotland and Northern Ireland. It concerns percentages above 20% with peaks in Northern Ireland of 34%. Whereas for a country like Bulgaria the estimate is a percentage above 40%. The European Commission speaks of more than 50 million people in the EU who are subject to energy poverty (EC, n.d.b). In a qualitative sense, it concerns the consequences that energy poverty has on a person's well-being. These are bad physical health, lower subjective well-being and suicide. On the other hand, Churchill and Smyth (2021) highlight a different side to energy poverty, which is about the factors that contribute to the experience of energy poverty. Churchill and Smyth discuss what they call the locus of control (LoC); the way in which people approach life and the way people deal with energy largely explain the seriousness of the situation. There is something to be done about this when people are in their youth. Churchill and Smyth suggest the need for early life intervention to nudge children and adolescents to become more internal on LoC, before LoC is stabilized. Several recent studies have suggested ways to reduce energy poverty, but promote positive behaviour, regarding gambling, savings and social capital, which are channels through which LoC affects the incidence of energy poverty.

In its research into energy poverty in the Netherlands, TNO describe energy poverty as follows: energy poverty exists when households have a low income in combination with high energy costs or a house of insufficient energy quality (translated from Dutch: Mulder, Longa, & Straver, 2021). The TNO study shows 550,000 energy poverty households, about seven percent of the total. 140,000 households use less energy than they would like. It is striking that, compared to poverty in general, energy poverty in areas outside the major cities has a high score, caused by comparatively poorer houses (Mulder, Longa, & Straver, 2021).

Energy poverty depends on the ownership situation of the houses. In the Netherlands, 57.4% of the 7.8 million houses are in the possession of the residents and 42.2% of the houses are rented out (0.4% is unknown) (Compendium voor de Leefomgeving [CLO], 2020). More than 2 million homes are owned by housing associations. Housing associations have committed themselves to making houses more sustainable through performance agreements with the state government and municipalities. The presence of housing associations has a positive effect on the prevention of energy poverty. The problem in the Netherlands in 2022 is the availability of housing in general and of affordable housing in particular.

Hanke and Lowitsch (2020) provide advice on how energy communities can involve low-income households based on several practical studies. This advice relates to: (1) linking energy subsidies to renewable energy community membership, capitalizing on future savings and making them available as a lump sum; (2) part of the capitalized amount may be used in a social way (1000 euros for education); and (3) an enabling framework for low-income households.

Energy autonomy and security of supply

Energy autonomy is a key driver for local energy system transitions to emerge. However, while the shift to more decentralized and distributed energy systems reaps various social, financial and environmental benefits; it simultaneously gives rise to new social and technical challenges. This section focuses solely on socioeconomic obstacles and conditions related to this.

Based on a literature review, Juntunen and Martiskainen (2021, 9) conclude that 'energy autonomy' is mostly associated with "a normative outcome that fosters self-sufficiency with social and environmental sustainability goals, in an economically viable way". Moreover, they discuss the increase in interest in the subject as can be deduced from the literature study. The question asked is "How is energy autonomy constructed as a socio-technical concept"? Juntunen and Martiskainen (2021) conclude that the interpretation of energy autonomy is about much more than the distinction between 'net' energy autonomy and complete energy autonomy. Energy autonomy, as a concept, entails political, economic and technological aspects. Motives for choosing energy autonomy are wanting to be independent from energy markets, environmental awareness, and securing energy supply in relation to threats such as climate change, war and terrorism. The study pays special attention to the economic dimension. Economic aspects in projects aimed at energy autonomy are the energy costs that are fixed during the life cycle, grid parity, less pressure on the network and job creation. A prerequisite is the agreement about sharing costs and benefits. It is also pointed out that large-scale projects can compete with small-scale initiatives, for example when it comes to the installation of wind turbines. The authors have noticed that projects aimed at energy autonomy generally do not lead to a desire to opt for a different economic system (Juntunen & Martiskainen, 2021).

There is an important link between energy autonomy and the topic of eco-villages. Eco-villages are residential areas where often like-minded people have set up a residential area or village together with the aim of living as locally and as sustainably as possible. In eco-villages, there is relatively much support for the pursuit of energy autonomy. This applies, especially, to many remote communities around the world, including Palestinian settlements in territory occupied by Israel, that are lacking basic services of clean water, shelter, heat and access to electricity. These areas are forced to opt for stand-alone systems (Sun, n.d.).

There are also examples of local energy initiatives, both from the residents themselves and from municipalities, in which efforts are made to meet their own electricity needs as much as possible at neighbourhood level. Examples of private initiatives are Texel and Heeten in the Netherlands (TKI Urban Energy, 2020). A sustainability stamp or the term 'ecological' are important selling points when selling houses. In light of this, the aim was also to achieve self-sufficiency in energy at district level, such as residential areas where there is a local heat grid (See e.g., MeppelEnergie, 2016).

Initial costs and financing

This issue has already partly been discussed in the sections on energy poverty and split incentives, but it relates mostly to the high up-front costs necessary to establish local energy system transitions. This section reviews obstacles and conditions from the socioeconomic and regulatory perspectives.

Socioeconomic

In relation to private home ownership, there is much to discuss on this subject. Thereby, it is important to make a distinction between making electricity consumption more sustainable and making heating more sustainable. To illustrate: solar panels for electricity can be installed for several thousand euros and the payback period is often within ten years; the financing issue is thus not very difficult. Whereas when it comes to heating, there are big differences depending on the kind of system that is used. First, an individual electrical heat pump based on water from the deeper subsurface needs high investments in insulation of the house, extra solar panels, drilling for the pipe, and purchasing and installing the heat pump. The investment for an average house amounts to 35.000 euro. Afterwards, there are low yearly energy-costs for heating, but the payback time can be up to 30 to 35 years (Taskforce Bouwagenda, 2019). Second, the investment in a heat pump based on air is much cheaper but often needs to be combined with another heat source in the Netherlands, so while the initial costs are lower, the yearly energy costs are higher. Third, a connection to district heating or the possibility of using green gas or hydrogen are accompanied by investments that correspond to the purchase of a new boiler. Dutch law prescribes that households connected to district heating do not pay more than households in a similar situation who are connected to the gas network (Expertise Centrum Warmte [ECW], n.d.).

Regulations

As stated, many local energy projects have high initial investment costs. Apart from financial obstacles, there are also related regulatory obstacles. One is European competition law, which can lead to favouring incumbent actors in the energy market over new actors. Moreover, in recent Greek Law 4759/2020, all Greek energy cooperatives are obliged, from 2022 onwards, to compete with private investors in bids to ensure the operational support of renewable energy projects (Law 4759/2020). Given that it is practically impossible to compete openly, this regulation virtually eliminates potential incentives to set up an energy cooperative by citizens and local authorities in the short term (Ziozas & Tsoutsos, 2021). According to Greenpeace and RESCoop.eu, it opposes the European institutional framework which identifies the specific characteristics of EU Communities, recognizes their social and developmental benefits and demands the protection of the inalienable right of citizens to participate in energy markets (REScoop.eu, Greenpeace Greece, WWF Greece, & Electra Energy, 2021). Finally, in Germany a regulation and an attempt to legally define energy communities and introduce exemptions for wind auctions largely failed; it resulted in project developers (mis)using the rule to secure their own project pipeline through ‘communities’ initiated and controlled by the developers themselves (Holstenkamp, 2021; Tews, 2018).

Demographic characteristics

Demographic characteristics also influence local energy system transitions. Obstacles and conditions have been found merely from the social acceptance perspective.

Individual energy behaviour and plasticity have been considered as one of the key drivers for sustainable transitions (Steg, Perlaviciute, & van der Werff, 2015). Two individual factors are considered to be salient in understanding why individuals decide to be more sustainable: knowledge and motivations (Steg et al., 2015). Understanding the importance of energy behaviour, the consequences of climate change, and the relationship between individual plasticity and climate change are some of the key components of ‘knowledge’ (Bord, O’Connor, & Fisher, 2000; Whitmarsh, Seyfang, & O’Neill, 2011). However, having knowledge alone is not sufficient as people need to be motivated to change their behaviour such as limiting the use of airplanes, purchasing and using energy efficient light bulbs, taking showers instead of baths, and living in apartments instead of houses (Bamberg & Schmidt, 2003; Harland, Staats, & Wilke, 1999).

Knowledge and motivation are associated with demographic characteristics. For example, people with higher educational attainment are more likely to be knowledgeable about climate change and individual plasticity, and people with higher income are more likely to have resources to invest in behavioural changes. Furthermore, many studies indicate that gender tends to be associated with people's perception and acceptance towards energy decentralization (Campos & Marín-González, 2020; Cecelski, 2003).

Several studies used quantitative and qualitative methods to analyse the relationship between demographic characteristics and social acceptance towards energy transitions. The findings tend to differ quite dramatically depending on the geographical and other social context and the energy transition challenge (Ingold, Stadelmann-Steffen, & Kammermann, 2019; Kim, Lee, & Kim, 2019; Krick, 2018; Lienert, Suetterlin, & Siegrist, 2015; Panori, Kostopoulos, Karampinis, & Altsitsiadis, 2022). Table 4 shows that for most demographic variables, the public acceptance towards energy transition and decentralization tends to differ depending on geographical context and the type of energy decentralization in question. Gender is particularly interesting. It is included in most studies that discuss demographic characteristics and energy transitions. It is evident from the studies listed in Table A.2 that gender is often a statistically significant variable, but the outcome tends to vary widely depending on the type of energy transition. In other words, there is a lack of a consensus regarding gender and other demographic variables and energy transition acceptance.

Table A.2 *Summaries of the Findings on the Relationships Between Demographic Characteristics and Energy Transitions*

Energy Transition	Geography	Gender	Age	Income	Education	Reference
Acceptance of RE	Switzerland	NS	More information available	NA	More likely to support subsidies	Ingold, Stadelmann-Steffen, and Kammerman (2019)
Green energy programs	Switzerland	Males are less willing to pay	Older people are less willing to pay	More willing to pay	More willing to pay	Motz (2021)
Acceptance of RE	Switzerland	Men are more likely to choose hydroelectric or nuclear	Older respondents are more likely to choose mix alterative	NA	NA	Motz (2021)
Wind farms	Germany	Women are less likely to support offshore and onshore wind compared to men	Older groups are less likely to support onshore wind	NA	NS	Sonnberger and Ruddat (2017)
Biomass	Europe (22 countries)	Better perception/intention to install among	NS	NS	Higher Education ? greater	Panori, Kostopoulos, Karampinis, and

		female			acceptance	Altsitsiadis (2022)
High voltage	German speaking part of Switzerland	Better local acceptance among female	NA	NA	NA	Lienert, Suetterlin, and Siegrist (2015)
Acceptance of RE	South Korea	NS	Younger → greater acceptance	Higher income → greater acceptance	Education: NA; Higher social status → greater acceptance	Kim, Lee, and Kim (2019)

Note. RE = Renewable Energy. NS = Not statistically significant. NA = Not applicable or not included in the model.

Some studies included other individual level non-demographic characteristics such as risk perception, benefit perception, and ideology such as support for renewables (Kim et al., 2019; Lienert et al., 2015). Generally, studies found that those that believed in the ideas of environmental sustainability were more likely to support energy transitions, but those that considered energy transition a risk were less likely to support it.

Because of the varied findings regarding demographic characteristics and energy transitions, it is difficult to conclusively argue that some demographic characteristics lead to a higher likelihood of accepting energy transitions. For energy transitions, context is often much more important than other technological developments because energy is often considered as a spatially situated social or community plan, not an individual choice (Fuchs & Hinderer, 2014; Miller & Richter, 2014).

Equity and psychology

Equity and psychology also play a role in local energy transitions. Obstacles and conditions related to this have been identified from the urban planning perspective.

Hearn, Sohre, and Burger (2021) point to the fact that innovations in integrated energy and urban planning often have questionable justice implications. This is a good entry point to the discussion of how aggregately optimal solutions can turn into serious obstacles to change if the local benefits and costs are problematically distributed across socio-economic and socio-spatial groups. From an integrated energy and urban planning perspective, this is placed in the backdrop of a wider under-researched problem of harmful climate change mitigation and adaptation interventions for vulnerable groups; see, for instance, Anguelovski et al. (2016), Blok (2020), and Sera et al. (2019). Normally, the evaluation of urban planning interventions necessitates the incorporation of measurable and therefore formalized, institutionalized criteria of well-being. For instance, equity and justice are foundational criteria for both urban economics and urban planning, respectively (Brooks, 2012). While economic theory, with a few notable exceptions, has no good capacity to evaluate equity and focuses on efficiency (Blair, 1995), the topic is a fundamental concern in the place-making efforts of planners (Brooks, 2012).

In energy planning, perception of fairness has been found to be a key factor for the social feasibility of proposed municipal plans. Huijts (2018) and Huijts, Molin, and Steg (2012) outline the connection between equity, fairness, and negative sentiments in the implementation of RES, pointing out the importance of understanding how the proposed changes relate to their perceptions of who wins, loses, or anyhow impacted by them, as well as what voices are heard during policy design. In particular, Huijts et al. (2012) highlight two key components in the aforementioned process: procedural justice (how citizens' views are reflected in sustainable transitions decision-making) and distributive justice (unequal costs and benefits of planning interventions). Moreover, Huijts (2018) draws deeper links to the internal states of citizens during the implementation of energy transitions, analysing emotions such as anger, fear, joy, and pride.

The connection to deeper psychological states in energy planning is rather important, because of more fundamental shifts currently at play concerning what should drive the urban planning process. As part of the general shift of planning to more bottom-up or adaptive approaches (cf. Schillinger et al. 2022), voices have been growing for the reconsideration of abstract foundational principles such as justice. For instance, Forester (2021) points out the incapability of planners to incorporate the notion of kindness in the planning processes. Similarly, Davy (2020) discusses the role of kindness in the planning process, and indeed reviews its underrepresentation as opposed to notions of justice, fairness, and equity.

Obstacles and conditions in tackling environmental issues

Environment and climate

Environmental concerns, particularly about climate change, are a major driver behind local energy system transitions. Various obstacles and conditions have been identified from three perspectives: regulations, urban planning and social acceptance.

Regulations

Electricity from renewable resources such as solar, geothermal and wind generally does not contribute to climate change or local air pollution since no fuels are combusted, despite for when producing the units However, whether forms of low- or zero-carbon energy are considered as renewable depends on regulations. For example, biomass might still depend on combustion and not be fully considered as renewable. Obstacles for growing biofuels might be limited due to protection of agricultural land. Electricity might be considered grey instead of renewable if fossil fuels are involved in the generation outside of the local energy system, even only as load back-up, and the same goes for hydrogen (Kåberger, 2018). Nuclear energy is zero- or low-carbon but not always considered a sustainable given the waste problem and safety risks.

Urban planning

From the perspective of urban planning, two topics are of interest in this regard: (1) Local Climate Zones in the local spatial planning context and (2) Shared Socioeconomic Pathways in the societal context.

First, from an energy commons perspective, Shareable (2018) reports that at the regional level, energy exchange among localities can even out seasonal or daily imbalances in supply and demand. However, balancing energy supply and demand can involve more than that. There is widespread recognition that climate change adaptation is not only an eventuality, but anyhow interacts and overlaps with climate change mitigation. This has meant that the local climate—meaning regional climate conditions as well as microclimate in specific neighbourhoods—can be treated not just as a boundary condition, to which the local energy system must respond, but as internal to the co-determination and planning of local sustainable energy supply and demand. Specifically for local sustainable energy communities, the microenvironment represents two things in terms of obstacles and opportunities: (1) a time-varying and often volatile factor that challenges the scheduling and delivery of demanded energy; (2) concurrently, a regulatable factor through nature-based solutions, ecosystem services, and climate architecture. Especially with respect (2), green and blue infrastructure and passive heating and cooling design techniques are solutions in the climate design of buildings and neighbourhoods. A recent development with respect to (1) came in the form of "local climate zones" (LCZs), which is an attempt to produce a typology of how neighbourhoods look like in connection to their energy balance. Therefore, plannable microclimatic factors can be conceptualized as conditions. More specifically, Stewart and Oke (2014) describes a universal typology of built environments—according to the height, density, materials, and use of buildings and the type of open public spaces found in a neighbourhood—the types of which have different effects on the neighbourhood's microclimatic behaviour and response to weather extremes, especially temperature extremes. The typology consists of ten "local climate zones" (LCZs) and planning choices surrounding them has consequences on the heating and cooling profile of buildings and neighbourhood, effectively providing a tool to understand how local RES demand and supply can be affected by neighbourhood design choices.

Second and nevertheless, choices such as the ones described above have also been positioned in more a fundamental context of societal factors affecting the overall sustainability and climate adaptation and mitigation paradigm that is followed by a society. The Shared Socioeconomic Pathways (SSPs) are five possible world outlooks towards sustainability and climate change, which produce internally consistent scenarios on energy and emissions, adaptation and mitigation, and population and the economy (O'Neil et al., 2016; Riahi et al., 2017). In particular, Riahi et al. (2017) describes the following scenarios. SSP1 (sustainability) describes a society with the most sustainable world view that takes the green road and implies low challenges to mitigation and adaptation. SSP2 (middle of the road) describes a society that poses medium challenges to mitigation and adaptation. SSP3 (regional rivalry) entails high challenges to mitigation and adaptation. SSP4: Inequality – A Road Divided (Low challenges to mitigation, high challenges to adaptation). SSP5 (fossil-fuelled development) describes the opposite of sustainable practices with a society that entails high challenges to mitigation but also low challenges to adaptation. Based on integrated assessment models, SSP1 and SSP4 are the societal contexts in which RES are expected to proliferate (Riahi et al., 2017), which in year 2100 corresponds to low-moderate climate forcing in the range of 2.0 W/m2 (SSP1) and 6.0 W/m2 (SSP4).

Social acceptance

Smart meters have been touched upon before, related to the acceptance of the technology itself. However, it must also be discussed in relation to the environment. Because of the intimate relationship between climate change and energy transitions, accepting smart grids and smart meters has also been connected to moral values, which are considered to act as drivers and barriers. For example, Milchram, Van de Kaa, Doorn, and Künneke (2018) found that those who understood and appreciated the smart grid technologies' contribution to environmental sustainability were more likely to support the technology.

Emission

Local energy system transitions are expected to contribute to emission reductions, though the extent to which depends on the mix and optimal use of technologies. Related to this, obstacles and conditions have been identified from the regulatory perspective.

Environmental regulations can become an obstacle for realizing renewable energy generation. All forms of energy generation have an environmental impact on air, water and land, besides emitting greenhouse gases. From a life cycle perspective, environmental impacts might arise in different stages of the energy production and distribution chain, for instance in fuel procurement, processing, storage, transporting, as well as in the actual energy production process and in waste disposal. All of these phases are directed by regulation. This can be environmental protection regulation but also planning regulations. Although biomass might be considered as renewable because regrowth of biomass is considered to compensate emissions, it still might cause air pollution. Differently, nuclear energy does not have emissions but waste problems. Apart from emissions, environmental laws also deal with other ecological aspects and hindrance. For example, hydro dams have issues related to nature, and solar and wind parks have environmental and natural effects, and lead to visual and noise hindrances.

Waste

On the one hand, energy can be produced from waste such as biomass residues, and on the other hand, energy is associated with producing waste such as decayed electric batteries. This issue is only quickly reflected upon from the regulatory perspective. Waste regulation can play a role in choosing technical innovations; for example, when considering that solar panels and batteries lead to forms of (chemical) waste that are difficult to recycle.

Spatial planning

Local energy system transitions require re-organizing spatial structures. From the perspective of regulations, the following needs to be discussed in terms of obstacles and conditions. Spatial regulations include rules for the siting of energy production locations or building permits. Construction of energy projects might be subject to planning and building regulations and major project might need an Environmental Impact Assessment (EIA).

Obstacles and conditions in tackling institutional issues

Trust, motivation and continuity

Trust, motivation and continuity are seen as main themes in initiating and sustaining local energy system transitions, though in multiple ways. First, in the way that communities appear to have more trust in local energy systems than more centralised systems; and second, in the way that governments should put trust in such community energy systems. In parallel, motivation as well as continuity in terms of business models are seen as crucial for collective putting in the effort and resources. Related to this, several obstacles and conditions have been found from three perspectives: regulations, governance and social acceptance.

Regulations

Regulations can create trust among market actors. Through regulations by higher tiers of government, uncertainties related to future regulatory change can be taken away, which in turn promotes investments in renewables (Biesbroek, Klostermann, Termeer, & Kabat, 2011; Burch, 2010; Corfee-Morlot et al., 2009; Eleftheriadis & Anagnostopoulou, 2015; Emilianoff, 2014; Kern, 2014; White, Lunnan, Nybakk, & Kulisic, 2013). If there is no continuity of regulation, this is an obstacle for systems change. A well-known example is the changes in grid feed-in tariffs in several countries. Feed-in tariffs are a policy mechanism that encourages renewable energy investment by paying producers or users to transfer excess electricity to the grid. Hence, it rewards entities for developing, installing, using, and conserving energy resources, such as wind and solar power. It should typically involve long-term contracts and cost-based compensation. For instance, Germany's feed-in tariffs ran for 20 years (Holstenkamp, 2021). The guaranteed electricity price and connection to the grid incentivized ordinary citizens and communities to invest in smaller scale solar, biomass and wind generation for their homes and local areas. However, if the guaranteed price becomes too much, and the feed-in tariffs are ending, investors (including prosumers) are confronted with changes in revenues. Alternatives like net metering and lowest-bid auctions are taking over, or even payments of fees for feeding into the grid are installed, which leads to distrust, demotivation of investment and discontinuity. In Denmark in 2012 costumers were promised a 20 year period for their PV installation in relation to net-metering. After 10 months the government stopped the incentive for PV installations, since there were much more connected PV than expected. Also in 2021, the net-metering agreement was stopped even for the costumers who had been given net-metering agreements during the 10 month period. (de la Hoz, Aliana, Coronas and Matas, 2021)

Governance

From a polycentric governance perspective as well, trust is a factor that influences local energy system transitions. This can be linked to the eighth and final feature of polycentric governance systems: *"the presence of trust and mechanisms to enhance trust across scales and levels"* (See deliverable 3.1). Local energy system transitions require the participation of local communities, and trust has demonstrated to increase citizen participation and engagement (Hill & Connelly, 2018; Kalkbrenner & Roosen, 2016; Koirala et al., 2018; Walker, Devine-Wright, Hunter, High, & Evans, 2010). This also includes trust in the governance system, including its institutions[16] and actors (Palm, 2021). As described in deliverable 3.1, more new institutions and actors enter the governance system in which local energy system transitions

[16] Please note that institutions are here defined as "any form of organization, regime, initiative, partnership or network" (See deliverable 3.1).

occur. This can result in an obstacle for local energy system transitions related to increased uncertainty about the roles and responsibilities of different institutions and actors and a lack of confidence in assuming such responsibilities (Rogers, Simmons, Convery, & Weatherall, 2008; Tarhan, 2015). In other words, low levels of trust in the governance system can become a constraint for the success of local energy system transitions. Whereas trust is not only necessary for individual local energy initiatives but also for wider acceptance of the energy transition in general (Wierling et al., 2018). To increase levels of trust, or confidence and acceptance, it has been argued that it is necessary to ensure the participation of various social groups, collective decision-making, equitable and transparent outcomes in the governance system (e.g., Tarhan, 2015; Wagemans, Scholl, & Vasseur, 2019; Walker et al., 2010; Wierling et al., 2018). Thus, such mechanisms to enhance trust in the governance system can be seen as a necessary condition for local energy system transitions.

Social acceptance

Assefa and Frostell (2007) argued that three indicators, namely knowledge, perception, and fear, can be associated with the acceptance of energy technologies. The study found that due to the significantly low levels of understanding on energy technologies, the respondents even failed to discriminately rank which indicator they perceived to be most important. Due to the availability of energy-related information when this study was conducted, some studies may claim that the findings may significantly change with time – that the respondents may become more aware of energy technologies over time with the wide spread of internet use. However, other studies have also suggested the lack of user knowledge as one of the main problems of energy technology adoption (Lee et al., 2020).

Milchram et al. (2018) also found that moral values related to privacy regarding smart meters were considered as a barrier. Moreover, data collection, cyber security, and lack of trust in organizations and energy companies were also considered as barriers.

Energy democracy

Energy democracy refers to the democratization of energy production and supply through new forms of organization. Various obstacles and conditions have been found from the regulatory and social acceptance perspectives.

Regulations

Even though the most recent EU energy Package puts consumer at the centre of the clean energy transition, enables the active participation of consumers and creates consumer protection rules; there might still be obstacles for real energy democracy (EC, n.d.). Key for the democratization of the energy transition is the possibility for citizens to get engaged in energy communities.

In the Renewable Energy Directive (RED II) ‘renewable energy community’ refers to a legal entity:

1. which, in accordance with the applicable national law, is based on open and voluntary participation, is autonomous, and is effectively controlled by shareholders or members that are located in the proximity of the renewable energy projects that are owned and developed by that legal entity;
2. of which the shareholders or members are natural persons, SMEs or local authorities, including municipalities;
3. of which the primary purpose is to provide environmental, economic or social community benefits for its shareholders or members or for the local areas where it operates, rather than financial profits.

Moreover, in the Internal Electricity Market Directive (IEMD) ‘citizen energy community’ refers to a legal entity:

1. which is based on voluntary and open participation and is effectively controlled by members or shareholders that are natural persons, local authorities, including municipalities, or small enterprises;
2. of which its primary purpose is to provide environmental, economic or social community benefits to its members or shareholders or to the local areas where it operates rather than to generate financial profits; and
3. which may engage in generation, including from renewable sources, distribution, supply, consumption, aggregation, energy storage, energy efficiency services or charging services for electric vehicles or provide other energy services to its members or shareholders.

These articles clearly define what energy communities are and what they are not. They should not be part of centralistic structures, use environmentally harmful technologies or have participation without power. Yet, the first challenge for the implementation of local energy system transition initiatives is to overcome local legal barriers in order to exploit the opportunities brought by the legal framework at EU level (Ines et al., 2020). Regulations promoting local energy system transition initiatives may be fruitful for their uptake, but might simultaneously present a weakness for long-term development of such initiatives (Brummer, 2018). Participation in energy communities might also be self-regulated by signing a declaration for real energy communities based on international characteristics for a real cooperative (International Co-operative Alliance [ICA], 2017; Rescoop.eu, n.d.). What energy democracy really means also depends on conditions under which an energy community can be formed, but also on national legal frameworks that condition the way energy communities need to operate as new market actor. Particularly, securing access to the national electricity grid for community energy projects is vital.

Although energy communities can take a variety of forms, the presence of members seems to allude to the legal form of ‘association’. The internal dimension has to do with the rules that apply between the energy community and its members. The preamble to Directive 2019/944 states that:

> Membership of citizen energy communities should be *open to all categories of entities. However, the decision-making powers within a citizen energy community should be limited to those members or shareholders that are not engaged in large-scale commercial activity* and for which the energy sector does not constitute a primary area of economic activity. Citizen energy communities are considered to be a category of cooperation of *citizens or local actors* that should be subject to recognition and protection under Union law. *The provisions on citizen energy communities do not preclude the existence of other citizen initiatives such as those stemming from private law agreements.* It should therefore be possible for Member States to provide that citizen energy communities take any form of entity, for example that of an association, a cooperative, a partnership, a non-profit organization or a small or medium-sized enterprise, provided that the entity is entitled to exercise rights and be subject to obligations in its own name. (recital 44 of the preamble, italics added for emphasis)

Thus, the paragraph above makes a distinction between communities governed by citizens and acting in a non-professional capacity, not engaged in large-scale commercial activities; and those activities in which citizens participate but where the governance is shared with professional actors. Importantly, the definition does not exclude the possibility of participation of ‘local authorities’ and SMEs as long as the non-professional character is preserved. According to Biresselioglu et al. (2021, p. 10)[17], the inclusion of the possibility for involvement of public actors and SMEs is an important development likely to facilitate energy communities.

[17] Legal Provisions and Market Conditions for Energy Communities in Austria, Germany, Greece, Italy, Spain, and Turkey: A Comparative Assessment’ Sustainability 2021, 13(20), 11212; https://doi.org/10.3390/su132011212

The Directive preamble (see recital 44 cited above) also provides that all legal forms should be open to energy communities. This variety, however, also means that energy communities must carefully research the different options available in their jurisdiction and make an informed choice. Different choices of legal form imply different answers to the following questions: who is liable for the obligations of the energy community and to what extent? Who takes decisions within the community and in what way? Which regulatory (and taxation) regime applies? For example, partnerships are generally legal forms which do not imply a separate legal personality and in which liability can extend to the members' private assets. Limited liability companies, on the other hand, have legal personality and, as the name implies, afford shareholders protection from liability. On the other hand, limited liability companies often have to meet requirements regarding publishing financial information. Other forms which are set up not for profit, such as foundations, prohibit the distribution of profits. Each legal form also comes with requirements regarding governance. For example, company forms (such as a limited liability company) have rules regarding the shareholder meeting, board membership, and the division of responsibilities between management and the board of directors (in case of a jurisdiction which requires two-tier boards, such as the Netherlands). The private law rules of the respective jurisdiction thus dictate specific requirements regarding the governance of an energy community. Considering all the above, the right choice of form for each cooperative will therefore depend on the type of collaboration between members, their views on governance, risk (e.g., tort liability), the sharing of costs, benefits, and responsibilities.

Social acceptance

Several studies engage with social movements and energy transitions. For example, Hess (2018) developed a multi-coalition perspective, which is used to assess the interactions among and between coalitions within energy transitions. He found that the concept of energy democracy is useful in bridging the gap between different types of coalitions and to integrate coalitions that have different goals under the umbrella of energy democracy. Another study published by Hess (2019) showed that ideals, objectives, and goals lead to different strategies and tactics in coalitions. In this sense, perceiving energy democracy as an objective has important practical implications because energy democracy as a concept can integrate and direct coalitions and social movements.

The importance of coalitions and social movements have been of particular importance in the Netherlands and the Dutch energy transitions. In the Netherlands, wind cooperatives have been active since the 1980s, and although the country has a strong market-oriented structure regarding energy systems, over the last 30-40 years, grassroots and community-based initiatives and movements have been gradually emerging (Oteman, Wiering, & Helderman, 2014). In addition to the wind cooperatives, which derive from anti-nuclear movements, new community initiatives and coalitions are emerging in the Netherlands. Oteman et al. (2014) argued that in the Netherlands, over 200 local initiatives involving renewable energy exist, which include 55 registered cooperatives. The main goals and objectives of these cooperatives include promoting renewable energy to private users and individual consumers and promoting and advocating for energy savings and efficiency.

One interesting case study involves a local energy community named "Aardehuizen," which literally translates to "earth houses" (Homan, Hoogsteen, Nebiolo, Hurink, & Smit, 2019). A small number of households that are residing in this community mostly use locally sourced sustainable energy. The community was built to promote sustainable living and to motivate and inspire others to live in a similar manner. The Aardehuizen community epitomizes energy citizenship built through coalitions and community empowerment.

Ownership

Local energy system transitions are either 100% community owned or co-owned with public and/or private entities. There are many ways in which such (co-)ownership is organized. This section describes obstacles and conditions in this regard from the regulatory and governance perspective.

Regulations

Several different legal forms are possible for community renewable energy that influence ownership, though the exact details and requirements are different from country to country. It depends on these rules whether this results in a regulatory obstacle to creating a certain form, to choose for profit or non-profit, and the way (collective) ownership and decision-making is organized. The first legal form is the cooperative. Cooperative societies are intended to primarily benefit their members. Membership is voluntary and open to anyone willing to accept responsibilities and risks. Additionally, members benefit from generated energy, and have a say in governance and profit allocation with one vote per member. The second legal form are legal partnerships, where individuals may decide to work together to establish a legal partnership with the aim of providing energy to a community. Unlike a cooperative, voting power will be determined by the stake that each individual puts into the company. As well as providing a community benefit, partnerships can generate a profit. A special type of partnership are public-private partnerships in which local authorities can decide to enter into the agreement with citizen groups and businesses, in order to ensure energy provision and other benefits for a community. The third legal form is sharing the financial benefits between shareholders. For instance, a limited liability company serving as a community interest company, while assets are dedicated to public benefit. Finally, there are also legal forms in which the public provides money or pays for services without a share or a say. For example, public trusts, crowdfunding, funds for community projects and investments in further energy projects or energy utilities.

Governance

From a polycentric governance perspective too, ownership is a factor that influences local energy system transitions. This can be linked to the second main feature of polycentric governance systems: *“tendencies of self-organizing that result in patterns of ordered relationships between institutions and actors in the governance system”* (cf. Schillinger et al. 2022). Local energy system transitions literature confirms that how institutions and actors organize in patterns of relationships can be seen as an important factor influencing local energy system transitions. However, yet another stream of literature that can be linked to this polycentric governance feature of self-organizing patterns of relationships focuses rather on how (co-)ownership is organized (e.g., Boon & Dieperink, 2014; Gorroño-Albizu, Sperling, & Djørup, 2019; Haggett & Aitken, 2015; Walker, 2008). As local energy system transitions are often developed at the community level though in collaboration with public and private institutions and actors, various legal and financial models of ownership have emerged throughout the years; for example, cooperatives, community charities, development trusts or shares owned by a local community organization (Walker, 2008; See also above). These different models represent different ways in which energy projects are owned or co-owned, due to which also the benefits are distributed differently. Benefits of local energy system transitions include local income generation, local control on for instance project scale and development, lower energy costs, and reliable supply and more (Walker, 2008). It can be seen as a necessary condition that these benefits are fairly distributed amongst the various institutions and actors involved (Boon & Dieperink, 2014; Gorroño-Albizu et al., 2019). This is specifically seen as an enabling factor for local support and acceptance crucial for local energy system transitions (Boon & Dieperink, 2014).

Locality

Locality relates to the claim that local energy systems can more efficiently and effectively provide energy services to local consumers than centralised systems. Obstacles and conditions in this regard have been found from three perspectives: regulations, governance and social acceptance.

Regulations

Based on the Renewable Energy Directive (RED II), renewable energy communities have shareholders or members that are located in the proximity of the renewable energy project itself. The definition of a citizen energy community in the Internal Electricity Market Directive does not have this restriction. Depending on the transposition to national legal frameworks, a regulatory obstacle can emerge for regionally or nationally operating energy communities from the REDII, which sometimes have local branches. This could limit the conditions under which such an umbrella energy community nor being in the proximity could operate (Coenen & Hoppe, 2021).

Governance

Also from a polycentric governance perspective, locality is a factor that influences local energy system transitions. This can be related to the fifth feature of polycentric governance systems: *"key role for local actions that accumulatively contribute to collective action"* (See deliverable 3.1). Naturally, it is inherent to the literature on local energy system transitions to discuss the role of local action. This literature generally seems to confirm that local action is key and accumulatively contributes to collective action, in this case transitioning to more sustainable energy systems. Scholars argue that the success of the energy transition depends heavily on successful transitions occurring at the local level (Brugger & Henry, 2021; Bulkeley & Betsill, 2003; Kern & Bulkeley, 2009; Young & Brans, 2020). Accordingly, a key role is assigned to local governments and communities, but also to urban societies and policy actors (Beermann & Tews, 2017; Caramizaru & Uihlein, 2020; Cheung & Ossenbrügge, 2020; Dobravec, Matak, Sakulin, & Krajačić, 2021). Hence, it can be seen as a condition that a key role is assigned to local action in the governance system in which local energy system transitions occur. A potential obstacle in this regard, however, is that the actual impacts of local energy system transitions remain poorly understood (Berka & Creamer, 2018; Caramizaru & Uihlein, 2020).

Locality, however, can also be related to the sixth feature of polycentric governance systems: *"recognition of site-specific conditions, including preferences, competencies and constraints of institutions and actors and their interactions"* (See deliverable 3.1). This can definitely be seen as a necessary condition for local energy system transitions. As Soares da Silva and Horlings (2020) put it: local energy initiatives are place based and their success depends on the physical space and conditions determining the way in which renewable energy is produced, but also on the specific institutional arrangements in place, resources available and capabilities of institutions and actors in that place. Hence, Walker and colleagues (2010, p. 2662) stress, for governance and policy, the need to guard against the idea that what works for individual local energy system transition initiatives, cannot simply be replicated or assumed for other initiatives. Local energy system transition initiatives come in various forms, *"not easily reducible to a single model entity or process, and likely not amenable to one-size-fits-all policy solutions"* (Hewitt et al., 2019, p. 5; see also Seyfang, Park, & Smith, 2013). For example, general and existing energy market regulations and policy instruments are largely inadequate and unsupportive for local energy initiatives (Ruggiero, Busch, Hansen, & Isakovic, 2021). Hence, it can be seen as a necessary condition that tailor-made policies are created for local energy system transitions in which locality is highly valued (e.g., Boon & Dieperink, 2014; Gancheva, O'Brien, Crook, & Monteiro, 2018; Ines et al., 2020; Palm, 2021).

Social acceptance

Locality has also been a central notion in understanding social acceptance towards energy decentralization. A study conducted in the UK (Devine-Wright & Batel, 2017) with the sample size of 1519 found that the respondents with more national attachments were less likely to support European grid integration, whereas the respondents with global attachments were more likely to support decentralized energy. The respondents that were locally attached were more likely to protest against having a power line nearby.

Another study showed the importance of locality. Although the advantages of onshore wind for renewable energy production are clear, the social acceptance towards onshore wind turbines or transmission lines directly link with how scenic the place is. Weinand, McKenna, Kleinebrahm, Scheller, and Fichtner (2021) found that in Germany, the municipalities that are considered as scenic (or the authors call it "high scenicness") are more likely to reject onshore wind and are more likely to accept solar.

Microgrids as the new form of energy decentralization show the benefits and strengths of locality. Guibentif and Vuille (2022) argues that microgrids can manage intermittency at a local level using renewable energy sources and can create local energy markets. These factors can lead to better social and public acceptance and also promote grid stability.

Support schemes and targets

Support schemes and targets are important drivers for local energy system transitions. Related to this, a number of obstacles and conditions are described in this section from the regulatory and governance perspectives.

Regulations

Originally, electricity sector regulations in the area of support schemes aimed to facilitate competition in activities that are not related to the grid infrastructure - i.e., generation and supply of electricity (Aiello & Pagani, 2016). New local energy systems might break with the traditional, natural monopoly of the classical DSOs on the local grid. A potential regulatory obstacle is that support schemes follow their own rules and are still based on the older liberalized energy market. Both support scheme rules and EU competition law might be favoring existing incumbent market players in energy projects.

Governance

From a polycentric governance perspective as well, support schemes and targets are factors that influence local energy system transitions. This can be linked to the first feature of polycentric governance systems: *"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"* (See deliverable 3.1). Without explicitly referring to it as a polycentric governance feature, various scholars have confirmed the increasingly diversified institutions and actors operating at multiple levels when it comes to local energy system transitions. Yet, despite the involvement of so many institutions and actors, an obstacle appears to be a lack of support for local energy system transitions. Especially a lack of access to subsidies, grants, feed-in-tariffs or other financial support mechanisms is frequently seen as problematic in case-studies across Europe (e.g., Bomberg & McEwen, 2012; Herbes et al., 2017; Irshaid, Mochizuki, & Schinko, 2021; Tarhan, 2015). Although the fact that local energy system transition initiatives continue to rely so heavily on financial support can also be seen as an obstacle in itself; the question arises how to make such initiatives less dependent (Lammers & Hoppe, 2018)? Accordingly, it is seen as a necessary condition that there is sufficient financial support for local energy system transitions (Caramizaru & Uihlein, 2020; Ines et al., 2020; Lammers & Hoppe, 2018; Seyfang et al., 2013; Wierling et al., 2018), but also in-kind support such as technical and administrative support (Bomberg & McEwen, 2012). Simultaneously, Bomberg and McEwen (2012) point out that in parallel it is important that local energy initiatives are sufficiently informed and skilled to find and exploit this support. Here, an important role can be played by intermediary and umbrella organizations (See section 4.4.8).

(Self-)governance

(Self-)governance relates to how local energy system transitions are governed or self-governed by its members, and how they are best supported in this regard. Naturally, obstacles and conditions in this regard are reflected upon from the governance perspective.

Specifically, from a polycentric governance perspective, the issue of (self-)governance can be linked to the second key feature of polycentric governance systems: *"tendencies of self-organizing that result in patterns of ordered relationships between institutions and actors in the governance system"* (See deliverable 3.1). As stated, local energy system transitions are organized in different ways (e.g. cooperatives, community charities, development trusts), but commonly involve a key role of citizens and the local community (e.g., Walker, 2008). Instead of citizens and communities being passive consumers while there is centralized control over the energy system, they gain control over their local energy initiative. Self-governance and self-organization is often seen the way forward, in line with democratic and inclusive ideals (e.g., Avelino et al., 2014; Frantzeskaki, Avelino, & Loorbach, 2013; Hasanov & Zuidema, 2018). Self-governance is, simply put, associated with forms of self-government, autonomy and self-rule (Cayford & Scholten, 2014); and self-organization with informal or semi-formal practices for collective action through proactive civic engagement and building coalitions with local institutions (Hasanov & Zuidema, 2018). However, in practice self-governance self-organization involves a complex arrangement between various institutions and actors. The challenge for local energy system transition initiatives is *"to find modes of organization and to design proper organizational principles and policies"* (Avelino et al., 2014, p. 15). According to Hasanov and Zuidema (2018) the process towards self-organization (and self-governance) includes largely three phases: mobilizing and motivating residents, organizing and reproducing the local initiative, and finally working with other groups and organizations. In sum, it can be seen as a necessary condition for local energy system transitions that they find modes of self-governance and self-organization.

However, effective self-governance and self-organization of local energy system transitions is challenged by various obstacles. These are distinguished by Avelino and colleagues (2014) as: the overarching challenge of trust, motivation and continuity; economic and financial issues; legal barriers; socio-cultural context; and micro-political conflict and struggles. According to the scholars, local energy system transition initiatives do not have all the abilities to address all these challenges themselves and remain dependent on other institutions and actors around them. For example, state governments are necessary to lift the legal and policy barriers, market actors could develop complementary services for community energy initiatives, and intermediary organizations can act as intermediary broker between the community and other stakeholders (Avelino et al., 2014). Hence, processes of self-governance and self-organization not only take place within the initiative itself, but also in interaction with broader institutional context (or: governance system) (Hasanov & Zuidema, 2018). Hasanov and Zuidema (2018) found that there are various pathways of interacting with these institutions, including public agencies, private actors and other local initiatives. In their interaction with these different types of institutions and actors, Wagemans et al. (2019, p. 16) have identified five governance roles of local energy system transition initiatives towards the energy transition based on a study in the Netherlands: mobilizing the public; brokering between government and citizens; providing context specific knowledge and expertise; initiating accepted change; and proffering the integration of sustainability. In sum, besides the condition for local energy initiatives to find modes of self-governance and self-organization, it is necessary that they interact effectively with the surrounding system of institutions and actors and to take into account different patterns in which this is organized.

Institutional design

Local energy system transitions involve a more diverse set of institutions and stakeholders compared to traditional energy systems, operating at the interface of community, policy and institutions (Koirala et al., 2016). Hence, while this does not necessarily imply that a new institutional structure needs to be established, it does require rethinking and reshaping existing structures. Obstacles and conditions related to this have been found from the regulatory and governance perspectives.

Regulatory

There are different institutional designs of local energy systems thinkable. It can be self-governed and initiated by citizens, it can be municipality led, or led by a municipality working with stakeholders and businesses. The choice of the ideal system depends on energy market and many other regulations that could form an obstacle (Hasanov & Zuidema, 2018).

Governance

Inherent to the polycentric governance perspective, institutional (re-)design is a factor that influences local energy system transitions. This is related to the first main feature of polycentric governance systems: *"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"* (See deliverable 3.1). Without explicitly referring to it as a polycentric governance feature, various scholars have studied the increasingly diversified institutions and actors operating at multiple levels when it comes to local energy system transitions. These institutions and actors include governmental authorities at the European, national, regional and local level; but also local utilities, project developers, companies, consumer co-operations and housing associations and, more specifically, citizens and households or civil society more generally (Boon & Dieperink, 2014; Gancheva et al., 2018; Lammers & Hoppe, 2018; Seyfang et al., 2013). In addition, there are umbrella and intermediary organizations amidst these public, private and community institutions and actors (Creamer et al., 2018; Soares da Silva & Horlings, 2020; Warbroek, Hoppe, Coenen, & Bressers, 2018); and transnational or translocal networks that cut across jurisdictions (Lee, 2017; Wretling & Balfors, 2021). Or, as Avelino and colleagues (2014) summarize, local energy system transitions involve institutions and actors from four sectors: the state, the market, the community and the intermediary sector. Moreover, be it implicit, the local energy system transitions literature recognizes this polycentric governance factor as a necessary condition. For example, Creamer and colleagues (2018, p. 2) argue that community energy is enabled by "*trans-scalar assemblages of overlapping and heterogeneously configured actors"*. Moreover, collaboration and networking between the many institutions and actors is argued to be a key facilitating factor for local energy initiatives (Horstink et al., 2020; Palm, 2021; Ruggiero et al., 2021; Wagemans et al., 2019).

However, the literature also points towards a potential obstacle. Scholars have argued that current energy policies existing at multiple levels are often too complex or even inconsistent, confusing and often changing, which is challenging effective planning of energy system transitions at the local level (Boon & Dieperink, 2014; Brummer, 2018; Seyfang et al., 2013). Even though misalignment at national and European levels can in some instances also lead to dissatisfaction and thus encouragement to take action at the local level instead (Boon & Dieperink, 2014), it is mostly seen as a key challenge to facilitate coordination between policies and strategies at local, national and European levels for increased consistency and coherence (Beermann & Tews, 2017; Dobravec et al., 2021; Gancheva et al., 2018). Accordingly, it can be seen as a condition for local energy system transitions that policies and strategies across institutions, actors and levels are coordinated and harmonized (e.g., Beermann & Tews, 2017; Brummer, 2018; Dobravec et al., 2021; Gancheva et al., 2018). How to do so, however, remains yet unclear from the existing literature.

Although *"the existence of overarching formal and informal rules and norms to ensure aligned objectives and conflict resolution in the governance system"* may address this at least partly. This is the third polycentric governance feature (See deliverable 3.1). Scholars have argued that local energy system transition initiatives should be linked to overarching policy objectives, as it can secure the support of stakeholders and citizens (Gancheva, et al., 2018; Palm, 2021). More specifically, it is argued that clear and ambitious targets for decentralized and local energy should be set at the national level, which should in turn be in line with European policies (Ines et al., 2020). Soares da Silva and Horlings (2020, p. 374) argue that *"without national and European policies setting the main goals and targets, the promise of a successful energy transition anchored in local energy initiatives remains largely unfulfilled"*. Such policy objectives, goals and targets can be considered formal rules and norms, however, there is perhaps even more attention in the energy system transitions literature for informal rules and norms. Scholars have specifically studied visions, discourses, norms and assumptions, mainly as obstacles for local energy system transitions in case-studies across Europe. For example, Beermann & Tews (2017) have found that in Germany the lack of a broadly shared vision on how to design and transform the future energy system has challenged coordination, conflict resolution and stakeholder participation mechanisms. Similarly, Kooij et al. (2018) found that political discourses on energy in the Netherlands and Sweden hamper the flourishing of grass root energy initiatives. More generally, Creamer et al. (2018) states that it is key to overcome variation in nationally and locally underlying assumptions and norms when it comes to local energy system transitions. Although it must be noted that there are also European countries in which visions, discourses, norms and assumptions have in fact been an enabling condition, such as in Denmark where political discourse on renewable energy enabled the emergence of local community energy (Kooij et al., 2018).

Finally, institutional (re-)design can be related to the seventh feature of polycentric governance systems: "*emphasis on experimentation and learning at different levels of governance, fostering innovation processes that are spilled over in the overall governance system"* (Schillinger et al. 2022). That is, not experimentation, learning and innovation in terms of the energy system itself, but in the way of social innovation and entrepreneurship, and experimenting with forms of organization (e.g., Becker, Kunze, & Vancea, 2017; Capellán-Pérez et al., 2018; Caramizaru & Uihlein, 2020). Local energy system transition initiatives come in different forms and sizes. These include energy cooperatives, community charities, development trusts, shares owned by a local community organization, local government projects with citizen participation, public-private partnerships, private companies and other initiatives (Hewitt et al., 2019; Walker, 2008). These can broadly be seen as types of social innovation, grassroots, niche innovations or laboratories of innovation (Beermann & Tews, 2017; Caramizaru & Uihlein, 2020). Such experimentation and innovation are argued to be necessary to intensify citizen and stakeholder participation, which in turn is key for awareness and acceptance of the energy transition (Beermann & Tews, 2017; Wierling et al., 2018). Hence, an emphasis on social experimentation, learning and innovation is inherent to local energy system transitions. However, this is not necessarily spilled over in the overall governance system in which local energy system transitions occur. As has been concluded earlier, market regulations and policy instruments are often inadequate and unsupportive for such social innovation (See section 4.4.6). In sum, experimentation, innovation and learning is a condition for local energy system transitions but can also be a potential obstacle if not sufficiently facilitated at the other governance levels.

Roles and responsibilities

Roles and responsibilities refers to citizens and communities becoming prosumers, and thus new actors and roles emerging in local energy systems. Obstacles and conditions have been found from two perspectives: regulations and governance.

Regulations

The SERENE project strives for low carbon, citizen centered local energy systems. Such systems ask for a new role assigned to citizens and energy communities. Older energy market regulations (Butenko and Cseres, 2015) that are being changed or under review might formed an obstacle for energy communities and for taking such a role in the local energy system. As we have seen, electricity suppliers for domestic customers needed to have a license for supply. Under current legal frameworks, prosumers were limited to selling their surplus electricity to their contracted supplier and are thus not entitled to freely supply surplus electricity to the market. And peer-to-peer energy exchange was neither possible, which means that a domestic customer cannot supply his generated electricity to other domestic customers within the local energy system. Another regulatory obstacle might be that an energy community would like to play the role of a DSO. Another regulatory question is if connected customers are member of the association or only customers, then the rules of the liberalized market decide that all customers are free to choose their own supplier. If an energy community is a system operator, the association still has to comply with rules on third-party access to the grid, meaning that customers keep the free choice of another supplier. Although it would be doubtful whether energy community members would decide to choose another supplier than their own energy community (Diestelmeier, 2021). Blanchet (2015) studied the role of two local energy initiatives in what he called the 'remunicipalization' of Berlin's electricity grid and concluded that the (potential) impact of local initiatives on energy systems and their governance has been underestimated. There is no regulation for a new system of rebundling, which gives energy communities the possibility re-bundle generation, system operation, and supply, in the hand of the citizens.

Additionally, the EU rules provide some safeguards to strengthen the position of energy communities on the energy market. Directive 2019/944 requires that member states “provide an enabling regulatory framework for citizen energy communities” (Article 16). Such a regulatory framework must guarantee some provisions regarding membership, consumption, and competition. Regarding membership, Article 16 requires open and voluntary participation, as well as the right to exit (See Article 16(1)a and b). This means a community cannot force an unwilling neighbor to be part of the community, nor can it prohibit the exit of a member who no longer wishes to participate (in the latter case the rules on switching in Article 12 apply).

Regarding consumption, Article 16 of Directive 2019/944 also provides that the members do not lose “their rights and obligations as household customers or active consumers”. Article 2(8) defines ‘Active consumer’ as follows: “final customer, or a group of jointly acting final customers, who consumes or stores electricity generated within its premises located within confined boundaries or, where permitted by a member state, within other premises, or who sells self-generated electricity or participates in flexibility or energy efficiency schemes, provided that those activities do not constitute its primary commercial or professional activity”. As evident, not only electricity generation, but also adjustment of behaviour is covered by this concept.

Thus, although they are engaged in e.g., generation through the community, energy community members still benefit from their rights as household customers (paraphrased as customers active in a non-professional capacity, art. 2(4) in the same directive) or as active consumers. The rights of the latter are detailed in Article 15 of the directive and include the right to operate directly or through aggregation, sell energy, participate in flexibility schemes, etc. Importantly, however, active consumers can also be subject to obligations, for example: that they are subject to network changes which ensure “that they contribute in an adequate and balanced way to the overall cost sharing of the system” and obligations related to financial responsibility “for the imbalances they cause in the electricity system” (article 15(2)(f).

Regarding their participation in the market, some additional provisions established in Article 16 of Directive 2019/944 are worth mentioning. With respect to the registration, member states are required to ensure that energy communities “are subject to non-discriminatory, fair, proportionate and transparent procedures and charges, including with respect to registration and licensing, and to transparent, non-discriminatory and cost-reflective network charges [...], ensuring that they contribute in an adequate and balanced way to the overall cost sharing of the system” (Article 16(1)(e)). This provision can be seen as guaranteeing the ‘level playing field’ for energy communities (see also recital 43 of the Directive). The requirement for non-discriminatory treatment is further emphasized with respect to access to electricity markets, and treatment with respect to the different activities of communities, including consumption, production, supply, operation of the distribution system, or aggregation (Article 16(3) of the same Directive).

Regarding non-discrimination, it is important to ensure that energy communities are not placed in a worse position than other players on the market. However, for the continued success of energy communities, provisions regarding fairness and proportionate treatment might be more important. Proportionality requires considering whether the benefits of the measures outweigh the costs and whether the burdens imposed are necessary and adequate given the expected results. Such provisions should take into account the specific challenges facing these communities. Article 16(1)(d) also mentions fairness, guaranteeing that energy communities are “subject to fair compensation, as assessed by the regulatory authority”. This is important, although it also raises questions of establishing fairness criteria.

Sharing of energy in the context of energy communities is also addressed. Article 16(3)(e) introduces the requirement for member states to ensure that energy communities can share electricity within the community. This means that sharing energy with, for example, a neighbor should be possible. However, the caveat is that this right (the Directive states that energy communities ‘are entitled’ to share the energy they produce) is to be exercised "without prejudice to applicable network charges, tariffs and levies, in accordance with a transparent cost-benefit analysis of distributed energy resources developed by the competent authority". Furthermore, in case of sharing, the community members keep their rights as final consumers (Article 16(3)(e)).

The Directive also provides possibilities for member states to put in place additional measures to enable cross-border energy communities, the possibility for communities "to own, establish, purchase or lease distribution networks and to autonomously manage them", and to benefit from exemptions regarding the obligations of closed distribution systems (See Article 16(2)(a-c)). The Directive also provides the possibility for Member States to allow energy communities to manage distribution networks in their area of operation (See Article 16(4)).

Governance

Also from the polycentric governance perspective, roles and responsibilities influence local energy system transitions. This can be linked to the first main feature of polycentric governance systems: *"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"* (See deliverable 3.1). As stated in the previous section (4.4.7), various scholars have indeed confirmed the multitude and diversified institutions and actors operating at different levels. These include institutions and actors scattered along the public and private divide. The literature simultaneously highlights the different ways and degrees in which these institutions and actors steer policies and influence, make and enforce rules. For example, national ministries formulate energy policies, which are guided by European Union directives and regulations, and while local governments are responsible for policy implementation (Palm, 2021). Whilst with the rise of energy communities – broadly seen as energy projects in which communities exhibit a high degree of ownership and control, as well as benefit collectively from the outcomes (Walker & Devine-Wright, 2008) – as well as increased policy support at European and national levels for community energy, the autonomy of private and community institutions and actors to influence these policies also increases (Creamer et al., 2018). Simultaneously, authors highlight that umbrella and intermediary organizations are important for building knowledge, skills and capacity across these institutions and actors (Boyle, Watson, Mullally, & Ó'Gallachóir, 2021; Rahmani, Murayama, & Nishikizawa, 2020). More importantly, the literature points towards the key role of umbrella and intermediary organizations in overcoming obstacles and ensuring conditions related to this multitude of institutions and actors: the involvement of multiple and diverse institutions and actors, the complexity or inconsistency of energy policies and the lack of support. Such organizations are seen as key in connecting public, private and community institutions and actors through boundary work (Bush et al., 2017; Creamer et al., 2018; Soares da Silva & Horlings, 2020). Moreover, they can translate national and European policy objectives to the local level, link local energy system transition initiatives to financial support schemes, or even play a brokering role by advocating and lobbying for policy reforms across levels (Creamer et al., 2018; Warbroek et al., 2018). Most prominently, they can provide in-kind support themselves by providing knowledge, establishing networks, facilitating learning and aggregating experiences or lessons (Boyle et al., 2021; Rahmani et al., 2020; Warbroek et al., 2018). In sum, it can be seen as a condition for local energy system transitions that a clear vision and division emerges on the roles and responsibilities across the multitude and diversity of institutions and actors involved.

Closely related to new roles and responsibilities that come along with new institutions and actors, is the fourth polycentric governance feature and factor to influence local energy system transitions: *"the presence of a broad range of both conventional and unconventional mechanisms for accountability"* (See deliverable 3.1). Local energy system transitions are a manifestation of decentralization of the energy system, resulting in increased participation of citizens and communities. On the one hand, it is often argued that as a consequence energy decisions *"are more inclusive, decision-makers are more representative, and there is a greater opportunity to hold decision-makers to account"* (Creamer et al., 2013, p. 4; see also Kunze & Becker, 2015; Vansintjan, 2015; Weinrub & Giancatarino, 2015). On the other hand, scholars argue that involving communities does not necessarily lead to more just or democratic outcomes (Berka & Creamer, 2018; Creamer et al. 2013). More specifically, Brisbois (2020) illustrates two important obstacles for accountability related to decentralization. First, as governance evolves beyond governmental authority, traditional checks and balances, most significantly democratic mechanisms (i.e. elections), to ensure accountability may no longer be as relevant (see also Van Kersbergen & Van Waarden, 2004). Second, as more and more decision-making nodes are included in the governance system, governing activities may become less transparent (Brisbois, 2020). It is key to address these implications, for example by introducing new mechanisms for accountability. Especially, since the various institutions and actors involved in local energy system transitions may have different interest but at the same time have different levels of power. For example, large-scale private actors and public agencies may be more equipped to negotiate than small-scale community actors as part of energy cooperative or communities (Becker, Moss, & Naumann, 2016; Sareen & Haarstad, 2020). Such tendencies of power imbalance and biased representation result in the risk of only achieving the energy transition goals of those institutions and actors with the greatest leverage (Sareen, 2019; Sareen & Haarstad, 2020; Sareen & Rommetveit, 2019); this illustrates the necessary condition for local energy system transitions to (re)design accountability mechanisms.

Opportunity structures, discourses and socio-technical imaginaries

A final institutional issue relates to opportunity structures, discourses and socio-technical imaginaries. Associated obstacles and conditions are reflected upon from two perspectives: social acceptance and societal debates.

Social acceptance

Discourse opportunity structures have also been found to have an impact on energy perception and acceptance. For example, Isoaho and Karhunmaa (2019) found that there is an intricate relationship between discursive choices, political approaches, and public perception. This could be due to the discourses of frames portrayed in the media, and they are found to change depending on political and industry opportunity structures. In other words, industry actors, government actors, and civil society organizations tend to change their frames around energy transitions based on the political and industry structures of a given time period (Lee & Hess, 2019). For example, the importance of opportunity structures is also shown in Panori et al. (2022) who found that local sources, local technology, cost savings, positive local impact all have statistically significant relationship to perceptions for using agrobiomass in heating applications.

Societal debates

The discursive situation can obstruct local energy transitions in two general ways, i.e. relating to the content of discourses, and relating to the process by which divergent discourses interact in the local context, potentially, to form a consensus discourse. A well-known distinction of discourses in the environmental domain in general and the energy transition in particular, which is acknowledged by several authors, is that of economy versus environment (Forget & Bos, 2022; Moss et al., 2015; Späth & Rohracher, 2012). Although there have been contentions that both dimensions can be combined in so-called ecological modernization discourses and that this can be a successful discourse to unite stakeholders (cf. Späth & Rohracher, 2012), such a view is also recognized to have a relatively narrow definition of sustainability (Moss et al., 2015). Reducing sustainability to an economic perspective has turned out to be obstructing an appropriate understanding of the empirical richness of public debates about the energy transition as well as risking not to take into account the existing discursive nuances which stakeholders bring to the table. Because it is difficult to express costs and benefits of technological alternatives, discourses often only talk about advantages and disadvantages (Sherren, Beckley, Greenland-Smith, & Comeau, 2017). In a study comparing the effect of discussing two different kinds of energy systems, Kojonsaari and Palm (2021) found that, depending on the way these systems were described and framed, undesirable notions of who would benefit and who controls the system could be triggered. Actually, an economy-focused discourse has been found to outright block system change, if it is not balanced with more in-depth aspects of social and environmental sustainability (Forget & Bos, 2022). Other topics that are important in discourses relating to local energy transition processes are, for example, participatory democracy, environmental sustainability, social equity and citizen shareholding (Moss et al., 2015). The temporal dimension also plays a role in local energy transition discourses. On the one hand, existing energy infrastructures not only lead to carbon lock-in, but also to discursive lock-in, by creating path dependence. In a public debate about dam removal in Canada, stakeholders noted that at least the damage of the dam was already done decades ago and that damage was known; any change in that system could also lead to new, unknown damage (Sherren et al., 2017). This phenomenon was called views of 'sacrificial landscapes' (Sherren et al., 2017). Thus, failing to address path dependence of the existing energy infrastructure, its potential framing as sacrificial landscape, the uncertainty of the new, future energy systems, can seriously impede the creation of support among local stakeholders. Others concur that discourses are bound to specific contexts and may, hence, not be successful in others (e.g. urban discourses in agricultural regions, or from highly industrialised regions in low-industrialised ones) (Späth & Rohracher, 2010).

There are several things to take into account when it comes to organising a *discourse formation process* on the local level. First, there is the danger of consulting only a limited range of perspectives. Typical issues are only 'listening' to the most vocal stakeholders (Batel & Devine-Wright, 2020), mistaking a minority discourse for a majority one (Sherren et al., 2017), excluding minority stakeholders or other relevant stakeholders (e.g. including a gender diversity) from the co-development of a consensual discourse (Sherren et al., 2017; Späth & Rohracher, 2010).

Second, the characteristics of stakeholders involved in discourse formation need to be taken into account. For example, stakeholders cannot be assumed to behave rationally (Parkins, Hempel, Beckley, Stedman, & Sherren, 2015) or to be open to change in the energy system (Sherren et al., 2017). There are also different levels of knowledge about the environmental issues at stake locally and in the wider context, or the energy system and technologies to be implemented (Sherren et al., 2017). This is crucial, as knowledge and experiences of individual stakeholders define which policy options they perceive as possible and impossible (Sherren et al., 2017). In a NIMBY-related study, it has also turned out that there is a risk for citizens to internalise a view of themselves as being unsuitable for participating in such decision making processes (Batel & Devine-Wright, 2020). Moreover, in negotiating and discussing with stakeholders a certain interpretive flexibility is required to understand the arguments they put forward, and to be able to connect arguments to produce a common narrative (Brugger & Henry, 2021; Mahzouni, 2019; Parkins et al., 2015). Actors who possess this flexibility could act as brokers or interpretive policy entrepreneurs (cf. Aukes, Lulofs, & Bressers, 2017; Batterink, Wubben, Klerkx, & Omta, 2010; Ingold, 2011).

Third, discourse and discursive moves are linked to politics and political decisions. For example, Moss et al. (2015) report that in their energy transition cases in Berlin, Germany, framing the debate in terms of finance and technology risked de-politicising the debate, thereby precluding genuine engagement with various views about how to develop the local energy system. Furthermore, they also noticed the result of this: already, institutional changes had been initiated without the existence of a consensual discourse. This led to an undesirable situation, in which an immature policy had been implemented that did not exploit the window of opportunity to the fullest (Moss et al., 2015). Other instances, in which discourse plays a strategic, political role, are when (a) citizens project their own perspective on others in an attempt to legitimise it, (b) citizens argumentatively defend themselves against being mischaracterised by other actors to prevent discursive hegemony, and (c) outsiders oversimplify local citizens' concerns by reducing these to a black-and-white NIMBY position (Batel & Devine-Wright, 2020; Parkins et al., 2015).

Fourth, there are barriers to successful local energy transitions due to processual effects of how the discourse formation is organised. It will be difficult to co-develop a feasible, sustainable solution for the energy system, if there is disagreement about what the problem in the energy system is (Brugger & Henry, 2021). Furthermore, stakeholders representing the incumbent or hegemonic discourse may exert pressure on stakeholders with divergent views, thereby blocking their serious consideration (Späth & Rohracher, 2012) or even disincentivising them to voice their views at all (Sherren et al., 2017). The exertion of such incumbent power can also take the shape of avoiding the discussion of the rules of the game (Späth and Rohracher, 2010). Späth and Rohracher (2010) also describe difficulty of organising local discourse formation processes due to the "creativity, strategizing and anticipation of possible conflicts" involved (p. 456). Finally, if discourse formation takes place in cyberspace as with the small-scale renewable energy technology discussion forums studied by Hyysalo, Juntunen, and Martiskainen (2018), this reduces the influence change agents can exert offline.

The literature also mentions several kinds of barriers relating to the role of *socio-technical imaginaries* in local energy transitions. First, as with discourses, the importance of temporal, social, cultural, spatial, and technological context is emphasised. Socio-technical imaginaries, though large-scale visions in principle, can depend on context, i.e. they may not "work" in or resonate with other contexts (Marquardt & Delina, 2019). This context dependence leads to several potential pitfalls in the implementation of new locally-integrated energy systems. Long-standing, local views about the character and process of socio-technical transformation may be neglected by outsiders 'dropping' technological innovations on communities (Burke, 2018). Cloke, Mohr, and Brown (2017) show, how avoiding to engage with the socio-cultural context in which projects should be embedded creates a disconnection with how "local communities envision their own futures and the role of energy in delivering and sustaining such visions" (p. 263). They also mention that the spatial distribution of stakeholders needs to be taken into account when constructing common future visions. A case study in Morocco found that national-level socio-technical imaginaries, though constructed around a notion of sustainable development, can reproduce existing hierarchies, which is especially problematic when this means the suppression of stakeholder voices (Haddad, Günay, Gharib, & Komendantova, 2021). Showing the relation between the symbolic character of socio-technical imaginaries and material reality, Smith and Tidwell (2016) found that existing energy infrastructures restrict what is thought to be possible and impossible in terms of socio-technical transformation of the energy system. Thus, if innovations come with visions of energy futures that do not take into account existing energy infrastructures and the ordering effect these have on stakeholders' visions, this can result in socio-economic change that is ineffective or resisted by stakeholders (Smith & Tidwell, 2016). Thus, the characteristics of local contexts mean that large-scale socio-technical imaginaries cannot simply be used everywhere in the same way, actually, their scope and resonance may even be limited to the contexts where they originally developed (Smith & Tidwell, 2016). As a consequence, it is disputable that socio-technical imaginaries and the energy infrastructures connected to them that work in one context can simply be upscaled or transferred in a copy/paste manner (cf. Marquardt & Delina, 2019).

A second aspect that comes to the fore in the literature is the tension that socio-technical imaginaries produce on the local level. Being national-level representations of collective energy futures, socio-technical imaginaries may not only differ from local-level visions, but even run counter to these (Cloke et al., 2017; Marquardt & Delina, 2019). Haddad et al. (2021) describe how the socio-technical imaginary can be imposed on local level actors by being positioned as a rationale for large-scale policy action and excluding local interests from the process (for similar top-down processes, see Corsini, Certomà, Dyer, & Frey, 2019). A considerable drawback of the probable incompatibility of socio-technical imaginaries coming from the outside or larger scale (vis-à-vis local communities) is that their incongruence with local visions may lead to sub-optimal solutions in the communities (Haddad et al., 2021). On the one hand, there may be inadvertent or purposeful effects of socio-technical imaginaries on the local level (Haddad et al., 2021; Marquardt & Delina, 2019; see also below). On the other hand, it is also logical that the socio-technical imaginaries become contested, and even diluted or diminished while discussing implementation on the local level due to their general, national-level character, which is probably not directly compatible with local contexts (Schelhas, Hitchner, & Brosius, 2018).

The existence of one dominant socio-technical imaginary on the national level goes along with alternative future visions contending for dominance – or 'hegemony' in discourse-theoretic terms. Imaginaries in general represent the future vision of a part of society (Marquardt & Delina, 2019). Struggles of dominant and alternative views of the future and the problems resulting from these struggles have been documented by various authors. There is the general problem of disregarding existing counter-narratives or 'counter-publics', i.e. parts of society adhering to alternative views of the future, because taking into account the visions of a too limited range of actors undermines a socio-technical imaginary's "durability and motivating force" (Burke, 2018; Schelhas et al., 2018). Similarly, if a socio-technical imaginary becomes too rigidly institutionalised, it can entrench new notions of futures that may soon be deemed undesirable but can only be transformed with difficulty (Tozer & Klenk, 2018). On the local level, the content of national-level socio-technical imaginaries can have different effects. First, local actors may simply resist being told by community outsiders how their future energy governance and economy *should* look (Schelhas et al., 2018). Second, the social sustainability effects of a changing energy system need to be taken into account (Burke, 2018). For example, in the United States, a comparative ethnographic study found that familiarity with the risks of a specific energy system (i.e. uranium and coal extraction) reduces the willingness to transform to another system where local employment, skills and knowledge are not taken into account (Smith & Tidwell, 2016). On the positive side, socio-technical imaginaries often include notions that are boundary objects, i.e. they are "both adaptable to different viewpoints and robust enough to maintain identity across them" (Star & Griesemer, 1989, p. 387), which allows socio-technical imaginaries to resonate with stakeholders who have different interpretations of core notions (Tozer & Klenk, 2018). In the end, the observation that socio-technical imaginaries are generic visions of the future and that local communities or energy regions are situated within their own specific context turns energy transitions into "complex processes (sometimes called wicked problems) that require continual attention to address interpretations and tensions" (Schelhas et al., 2018, p. 191).

The final set of potential obstacles related to socio-technical imaginaries relates to its role in energy politics. As Haddad et al. (2021) note, the language and imagery of the socio-technical imaginary provides local stakeholders with an opportunity to formulate their own political criticisms, claims, and demands. Noting the boundary character of notions that are comprised in the imaginary, it then becomes possible to reframe its meaning. Furthermore, reducing the geographic reach of an imaginary is an act of political power, as it requires delegitimising alternative futures. Furthermore, reducing the geographic reach of an imaginary is an act of political power, as it requires delegitimising alternative futures. Smith and Tidwell (2016) remind us that socio-technical imaginaries, thus, not only represent visions of the 'good life', but also entail social justice problems, when some stakeholders have the symbolic power to 'choose' the socio-technical imaginary. If the set of stakeholders participating in energy transition processes is not sufficient. If the set of stakeholders participating in energy transition processes as well as policy support is insufficient, this "limits the potential for designing desirable and sustainable energy futures" (Marquardt & Delina, 2019, p. 100).

The problems that can arise for local energy transition projects suggest that it is important to consider the content of existing discourses and socio-technical imaginaries as well as processes of formation, (re-)negotiation, and resistance surrounding them. The literature proposes various conditions that need to be met to make sure that discourses and socio-technical imaginaries do not stand in the way of successful innovation processes[18]. The literature on local energy discourses and socio-technical imaginaries is quite distinct, justifying a separate treatment of both when it comes to barriers. However, looking forward to the conditions that need to be organised locally to increase the probabilities of successful local energy transition projects, the suggestions that can be distilled from the literature will be viewed together.

In general, and in accordance with the consensus in innovation literature (Bellamy, Chilvers, Pallett, & Hargreaves, 2022; Kemp, Loorbach, & Rotmans, 2007; Sovacool et al., 2020), the potential pitfalls indicate a necessity for local energy transition projects to engage relevant stakeholders in deliberation processes about the envisioned socio-technical innovations; if not formally inscribed in project

[18] Where not explicitly formulated as such, conditions below were logically derived from the findings and conclusions of the sources.

descriptions, then at least to the extent possible. In terms of creating constructive and productive stakeholder engagement for discourse and socio-technical imaginary negotiation, we distinguish three elements: purpose, preparation, and process.

It becomes clear that, given their role in the use and dealing with new energy infrastructures, the purpose of stakeholder engagement needs to exceed merely informing them. Rather, stakeholder engagement is organised to provide an opportunity for participants to converge towards a shared discourse or imaginary about the energy system in question and motivate them to work towards this common goal (Corsini et al., 2019; Kojonsaari & Palm, 2021; Marquardt & Delina, 2019). This holds for citizens as well as innovators themselves. Given that both existing and new energy system designs can be interpreted differently by or have different symbolic meanings for each stakeholder, e.g. concerning the commodification of nature (Forget & Bos, 2022; Moss et al., 2015), and stakeholders can be subject to cognitive lock-in, because they are familiar with the existing energy system only (Kojonsaari & Palm, 2021), stakeholder engagement processes geared towards developing shared discourses and imaginaries present opportunities to “move forward with otherwise intractable conflict and policy grid-lock” (Parkins et al., 2015, p. 10). As Cloke et al. (2017) contend, stakeholders’:

> *different ways of knowing, performing and imagining […] energy in daily life […] need to be brought into dialogue with one another to ensure a holistic understanding of how each project can be adapted and implemented to meet each community’s energy needs and aspirations. (p. 264)*

As contextual factors influence which (combination of) environmental and economic discourses and imaginaries becomes dominant (cf. Späth & Rohracher, 2012), there are several aspects that need to be assessed before bringing stakeholders together. Innovators need to investigate the central topics of the energy transition debate on the local level, central topics on other levels insofar as they influence the local level, who voices these topics in what way, what the power relations between stakeholders are, and how stakeholder location, e.g., urban/rural, makes a difference (Batel & Devine-Wright, 2020; Brugger & Henry, 2021; Moss et al., 2015; Smith & Tidwell, 2016). Among others, this also involves an understanding of how existing and potential new energy infrastructures may be appropriated or rejected by local stakeholders (Forget & Bos, 2022), or which aspects of energy democracy play a role (Burke, 2018). On a more abstract level, innovators would need to know in what sense stakeholders are aware of what is said about them by others, why and how this affects them (Batel & Devine-Wright, 2020).

Organising stakeholder engagement processes requires attention to the range of stakeholders to be involved, content and timing of deliberations, and general process characteristics. Especially, if incumbent decision-making processes rely on a small range of stakeholders and consciously exclude other stakeholders who are nonetheless affected by the decisions taken, it can make sense to open up these processes (Corsini et al., 2019). Corsini et al. (2019) note that community experiences can provide useful inputs to transform the views associated with the energy system. Several sources mention that it is crucial to engage with broad ranges of stakeholders to understand which discursive topics apply and which imaginaries resonate with them (Smith & Tidwell, 2016; Späth & Rohracher, 2010). It can also make sense to involve stakeholders who can “mobilise resources across levels of action and stages of development” to ensure commitment and cooperation (Mahzouni, 2019). Thus, stakeholders need to be carefully selected to go beyond the ‘usual suspects’. One example of this is to not only include community protagonists, but also ‘regular’ citizens, who are not normally voicing their visions, concerns, and interests loudly and visibly (Batel & Devine-Wright, 2020). Even when conflicts can be anticipated, it remains paramount not to pit stakeholders against each other as “political enemies”, but emphasise that they contend for dominance of their discourses and imaginaries as “political contestants” (Burke, 2018). Such terminological subtleties can not be taken lightly by the innovators who organise the engagement process, as it can determine the rapport among stakeholders. Finally, innovators and/or project partners must be aware of their own role and be reflective of their own influence in the innovation process, as they are intervening in local stakeholders’ or communities’ energy discourses or imaginaries (Batel & Devine-Wright, 2020; Reusswig et al., 2016).

What, then, do innovators need to deliberate with the relevant stakeholders? As socio-technical innovations are borne from innovators understandings of the problems of existing energy systems, they can also originate in discourses or imaginaries that are distant from the ones at play in the local community. Thus, it can make sense to make these discourses and socio-technical imaginaries explicit and reflect on them (Schelhas et al., 2018). This would mean innovators and other stakeholders would have to discuss early on (and not ex post facto) the advantages and disadvantages of energy systems, including the consequences of present and proposed energy infrastructures beyond mere economic and technical aspects, and also focus on the path-dependencies of current energy visions and uncertainties of future visions (Kojonsaari & Palm, 2021; Reusswig et al., 2016; Sherren et al., 2017). This should not only cover stakeholders "definitions, purposes, control mechanisms, and ownership [ideas]" (Kojonsaari & Palm, 2021, p. 12), but also values, expectations and how their views will be taken into account, i.e. the rules of the game (Marquardt & Delina, 2019; Späth & Rohracher, 2010). If timing is crucial in this kind of processes (Reusswig et al., 2016), the rules of the game should be clear early on and not leave stakeholders in limbo about what they can expect from the process. Such deliberations could be supported by illustrating with inspiring good practice examples (Mahzouni, 2019)[19]. Moreover, although Späth and Rohracher (2010) suggest that there might be benefits in engaging in conflict avoidance, e.g. by using boundary objects, others are more open to the productive potential of addressing tensions overtly. They assert that there may be no way around discussing underlying oppositions between stakeholders in a constructive manner and nuancing positions that may otherwise be simplistically labelled as "NIMBY" (Not In My BackYard) (Batel & Devine-Wright, 2020; Reusswig et al., 2016). Besides oppositions on the same level, relations of discourses and imaginaries across levels should also be considered, i.e. how do local-level perspectives relate to the national-level socio-technical imaginary or energy discourses in other places (Sherren et al., 2017; Späth & Rohracher 2010, 2012). Finally, innovators should take into account how gender characteristics make for different views of the situation (Sherren et al., 2017).

According to the literature, stakeholder engagement processes aiming for convergence of energy discourses and socio-technical imaginaries have to be designed such that they are perceived as legitimate by stakeholders, e.g. by involving accepted energy experts who are known for their integrity, and that they maximise trust, credibility, publicity, and authority of the process and its outcome (Späth & Rohracher, 2010). Thus stakeholder engagement processes are constructive and productive if there are actors with "strategic capacities to construct and shape collective visions", who can serve as brokers or intermediaries and ensure the aforementioned process characteristics (Späth & Rohracher, 2010). A final aspect of innovation processes and stakeholder engagement within them is that they cannot be seen as one-off or punctuated. To increase chances of retention and usefulness, the co-evolution of innovative technologies and the societal relations they are to be embedded in has to be understood as an ongoing process. This means that discourses and imaginaries must be reflected upon together with stakeholders at more than one point during a project and adjusted, if necessary, e.g. because changing socio-technical regimes or landscape events require this (Moss et al., 2015; Tozer & Klenk, 2018).

[19] If required or appropriate, digital and online tools can be positioned to improve stakeholder interactions. Corsini et al. (2019) call for more attention to the way in which digital tools can play a role to support stakeholder engagement, e.g. for visioning and imagining processes. This call is corroborated by the internet forums discussed by Hyysalo et al. (2018), which served as an informal channel for stakeholders to inform themselves about the opportunities of new energy technologies and discuss about them. Thus, digital tools may present opportunities to extend face-to-face interactions to online interaction spaces, thereby reducing thresholds to participate in more formalized local energy projects.

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