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Use of open-source P2P energy sharing platforms for energy Democratization

Deliverable D1.2
Active consumers' needs and social parameters

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Disclaimer

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[1] https://u2demo.eu/

Executive Summary

This deliverable reports on a study within the U2demo project, which investigates the values, capacities, and fair treatment of active energy consumers within the development of energy sharing platforms. The project aims to inform the design and implementation of inclusive, effective energy sharing arrangements that are centred around the values of citizens in energy communities. In doing so, the project ensures that this new technology will positively contribute to a democratic and equitable energy system where active consumers benefit from energy efficiency measures. Findings from this study will be used by technical developers within the U2demo project to develop IT architecture, sharing algorithms and platforms designs that correspond to the requirement of active consumers.

The study is conducted in energy communities spread out across four pilot sites in Europe. These pilot sites vary in the types of citizens residing there, who have different experiences with energy technologies, cultural backgrounds and geographical contexts. Preceded by initial conversations with representatives of the pilot sites, the main research in this work engages with the members of the pilot sites through semi-structured interviews. This way, the study practices an iterative approach to performing design research where the multiple phases of the research inform each other. To accommodate research in four national contexts, teams of researchers that speak the local languages are assembled and research methods are aligned to produce coherent results. A total of 21 pilot members participated in the study. The study took place before the implementation of the energy sharing platforms in the pilot sites, meaning that the members of the communities had little to no prior experience with energy sharing technology. Follow-up studies later in the project will verify and expand upon the statements captured in the results of this deliverable.

We find that across the pilot sites there are many similar ideas about the interactions with energy sharing platforms, apart from a few more specific preferences. All pilot members are motivated in the first place by ambitions to reduce their energy bill and contribute to sustainability goals. Furthermore, we see how many would like to reinvest savings in communal infrastructure and how some aspire to be less dependent on national pricing structures. Capacities of the pilot members differ greatly as the level of knowledge with regards to energy systems (energy literacy) is limited, especially for the Belgian pilot and Portuguese pilot. Still, all participants in the study welcome the idea of advanced insights into their own consumption and production patterns. When these insights are presented in an actionable manner, this information could enable them to offer flexibility at times of grid congestion. Whether this flexibility will materialize in practice, however, is highly influenced by external factors and community composition (in terms of energy profiles).
With regards to the *fairness* of sharing energy, we found a consensus across the pilot sites where members deem it fair that anyone in the pilot has an equal opportunity to make use of any surplus energy, after the owner of the production assets has had a chance to make use of it. In addition to that, there is a preference to keep the energy close to the source, distributing energy amongst a gradually increasing amount of involved parties. Starting from the community itself, remaining surpluses of energy would then be shared with neighbouring municipalities and beyond. 'Procedural fairness' is embodied by the communities' governance structures, where we see that members only want to be directly involved in important decisions and are fine with delegating day-to-day decisions to a single leader or manager that they trust. Recognition can take place through the visual representation of the pilot values in interfaces and dashboards.

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Acronyms

BRP	Balance responsible party
DER	Distributed Energy Resources
DR	Demand Response
DSO	Distribution System Operator
EC	Energy Community
EU	European Union
EV	Electric vehicle
HCI	Human-Computer Interaction
PV	Photovoltaic
P2P	Peer-to-Peer
TSO	Transmission System Operator
UX	User Experience
WP	Work Package

1 Introduction

The U2Demo project aims to create innovative, consumer-centred energy management strategies that facilitate widespread participation in Peer-to-Peer (P2P) trading and Energy Sharing. This initiative aims to promote equitable and democratic access to sustainable energy resources by developing opensource, non-proprietary tools and a platform that enable energy sharing. Essential to the development of such a platform are requirements that originate from the network of active consumers and stakeholders that aim to make use of it. Those requirements need to inform the developers of energy management technologies of the intricacies of social contexts and the values that are exchanged. This document reports on an inquiry into four energy communities and their members, from here on referred to as the U2Demo pilot sites. The document starts with a description of the objective and scope of this assignment in more detail after which we outline the setup of the studies conducted and reporting layout.

1.1 Scope and Objectives

This report is part of the activities of work package (WP) 1 that will amount to the creation of a harmonized framework describing the activities of active consumers in terms of roles, responsibilities, underlying motivations and social relations. To this framework, the WP adds an analysis of the regulatory, social, and business context of the U2Demo pilots and future eco-system. This report describes the activities and outcomes of Task 1.2, focusing on the social context of active consumers.

1.1.1 Task description

Decision support algorithms such as energy management systems can empower consumers and prosumers (consumer that also produce energy) to actively engage in energy and flexibility services. By promoting negotiation and collaboration among these households, energy-efficiency can be maximised to their benefit. Besides resulting in various direct benefits, this collaborative approach to energy-efficiency can greatly enhance the relationships between them. In practice, however, these peers are neighbours, members of energy communities and/or local businesses that share a responsibility for the way that energy will be distributed, and specifically at what price. This comes with many social implications, possibly altering relationships between them. Together with other factors that are influenced by the design of P2P systems, such as the (perceived) transparency, fairness, usability, environmental benefits and monetary gain, these social implications are of vital importance when implementing P2P technologies.

Task 1.2 of the U2demo project aims to investigate what motivations members of active consumer initiatives might have to adopt P2P systems, what could enable them to engage with P2P systems (considering the aforementioned factors) and how social tensions that arise from sharing valued resources can be resolved. Specific focus will be put on identifying the values that active consumers can share and how this exchange can be agreed upon. To achieve these objectives, the research addresses the following questions to be answered:

1. What motivations do active consumers have that are relevant for energy sharing activities?
2. What social relationships do active consumers form with community members and how might these be affected by sharing energy?

3. To what degree are active consumers able to participate in energy sharing activities (energy literacy) and how could this be facilitated?
4. How can principles of fairness be applied in the energy sharing process and how might this resolve matters of energy poverty?

Answers to these questions will be used to formulate a set of end user requirements, constraints and preferences that should be considered in the implementation of the energy sharing tools and platform by the other work packages in U2demo. Accompanying these tools will also be a set of guidelines and takeaways for increasing the engagement of consumers and adoption rate of the technology.

1.1.2 Scope of the work

The P2P Energy Sharing tools will account for existing flexibility services managed by transmission system operators (TSOs) and distribution system operators (DSOs), including both implicit and explicit demand response (DR) programs and local flexibility markets, as well as dynamic capacity and price signals/contracts. To guide the research and development into matters of consumer engagement and design requirements, we conduct all research around concrete points of interaction between peers that are related to these activities. We consider these 'touchpoints' the main areas for consumer-centred research with regards to enabling P2P energy sharing activities within the U2demo pilot sites. These touchpoints and the activities that underlie them are the result of an initial series of interviews with the pilot leaders about their communities and initial ideas for energy sharing, illustrated later in the research study overview as 'research phase 1' (Figure 1.1). A detailed description of the activities that are discussed in these interviews can be found in ANNEX I. In total, this task will conduct a study along 3 such points of interaction:

1. *Setting up for energy sharing activities*
   The first touchpoint concerns the preparations made within a collective of peers to start the implementation of P2P energy sharing. For some initiatives, this starts with getting a sufficient number of citizens or local businesses involved and taking inventory of the available distributed energy resources (DERs; e.g., solar panels, batteries) that can be shared. This will need to be followed by the definition of some core principles that largely dictate the sharing and distribution of resources.
2. *Interacting with energy sharing services and tools*
   Once a choice for energy sharing activities and tools has been made, the peers will in time start interacting with the energy sharing system itself. Through various means such as online portals or apps, the peers will need to shape their participation in an energy market to maximize personal and communal value. This process can involve manual interactions as well as the instruction of automated processes. Throughout these interactions, elements of play can be introduced to promote specific behaviours of influence trade-offs between values (e.g., sustainability vs price).
3. *Billing and settlement*
   After the operations, the value of shared energy and participation in services should be materialized and communicated to the peers. In this settlement process, the peers will get insight into the result of automated processes and should be able to evaluate the energy sharing process.

1.2 Research structure and readers' guide

This section outlines a study setup with various phases, including the initial conversations with pilot leaders. We also introduce the various pilot sites and their involvement in the study. Lastly, an overview of the report structure provides a handy guide for navigating this document.

1.2.1 Study setup

The complete setup of the study in this task is shaped by two phases of research work and one phase in which a reflection on the work is made and conclusions are drawn. Following design research methodology, each of the phases is characterized by a stage of gathering insights (diverging) and formulating outcomes (converging), also known as the double diamond[2]. This entire process is visualized in the overview presented in Figure 1.1. Although the figure seems to display a linear process, the phases displayed are only sequential in the sense that research activities relate to different parts of the implementation of P2P energy sharing. Findings from any of the research activities, however, can still provide new perspectives and nuances on matters researched previously.

As discussed earlier, the first phase is exploratory and encompasses a few conversations with pilot leaders. This provides initial background and contributes to the scoping of the work in the task. Subsequently, phase 2 contains the main focus of this deliverable and covers detailed interviews with a great variety of active consumers across the pilot sites. The insights from these interviews are then translated into the requirements for energy sharing platforms and tools. Additionally, the research questions are revisited to provide extra detail on the motivations of active consumers, social relationships, energy literacy and fairness. A final reflection also provides insights into the differences and similarities between the pilot contexts.

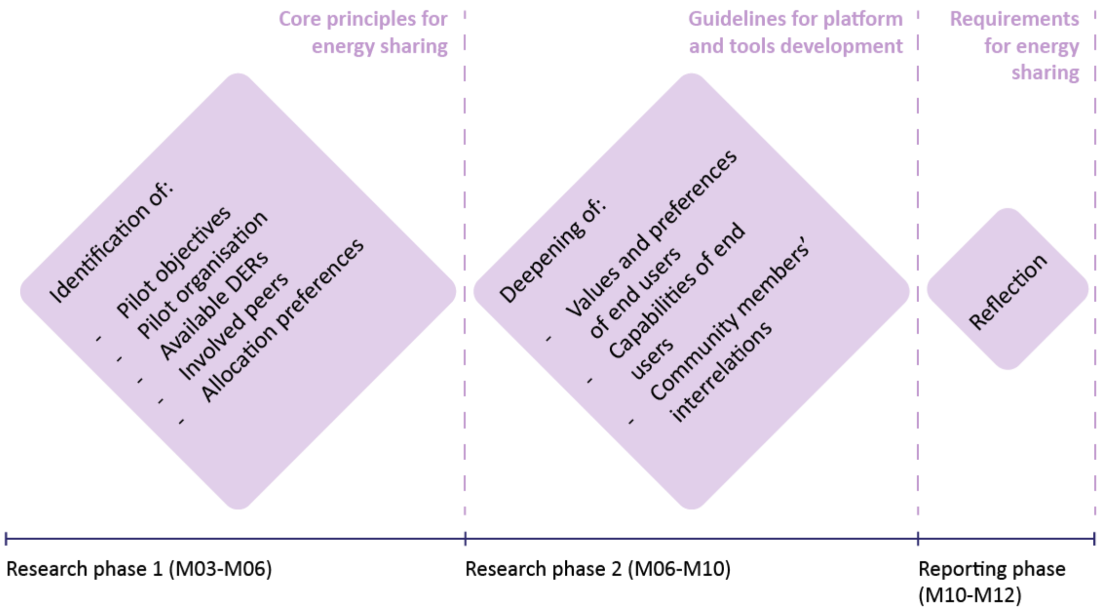


Figure 1.1 – Overview of diverging and converging research activities in the diamond structures

[2] The Double Diamond - Design Council

1.2.2 Pilot sites

Central to the research in this task are the four diverse Energy Communities that are the U2demo pilot sites. Each of these communities is characterized by unique contexts, active consumers and governance models. Both the members of these communities and the community managers are subject to the research activities described earlier and have an active role in informing the design requirements resulting from this task. We provide a short introduction of the pilot sites here and list more specific information in the background of this report.

- Portugal, Valverde
  Valverde is a small rural village in the countryside of Évora. It has around 450 inhabitants and 200 residential buildings connected to the low voltage grid. A group of 10 households is setting up an energy community to make better use of their solar panels.
- Italy, Vallevignale
  The demo is located in the central part of the Italian peninsula, in Abruzzo region. The site is placed in Vallevignale, a small town of about 60 people in the municipality of Notaresco, Teramo. The community consists 10 buildings, mostly inhabited by family members and close relatives that invest in a more future-proof energy systems for their area.
- Netherlands, Scheveningen
  Living Lab Scheveningen is the flagship programme of The Hague's Smart City activities. In the lab, 3 innovative beach side businesses aim to use energy more efficiently with help of the municipality and the harbour control center. Their approach encompasses societal challenges around environment, safety and sustainability, all in the public space.
- Belgium, Mechelen
  The demo is located in the Otterbeek suburb of the city of Mechelen, a medium sized Belgian city of approx. 87.000 inhabitants. Here, energy cooperation Klimaan is working with a social housing cooperation to provide cheaper, sustainable energy to roughly 197 households.

1.2.3 Readers' guide

After this introductory chapter, five chapters will follow; each divided into their respective sub-chapters.

- Chapter 2 outlines the relevant literature that is required to formulate a study on the social aspects of energy sharing activities. In this chapter, the background, we also provide a general introduction of the pilot sites based on initial conversations with the pilot leaders.
- Chapter 3 introduces the study method.
- Chapter 4 presents the resulting findings in detail per national context
- Chapter 5 presents a synthesis of the results and aims to distill overarching insights that lead to design requirements.
- In chapter 6, we reflect on the study to identify shortcomings and propose future directions for follow up studies and activities.

1.3 Relationship with other tasks

The work presented in this deliverable also contributes to the progress towards other tasks within this work package and the produced findings will be applied in the development of platforms and tools in the technical work packages. Here, we outline three main links between this work and other tasks that concretise the knowledge that will be transferred within the project upon the completion of this task.

1.3.1 WP1: harmonized activity list for peer to peer-based energy sharing and services

The overall goal of WP1 is to deliver a harmonized framework describing the activities of active consumers (groups) in terms of roles, responsibilities, underlying motivation and social relations. The research in this task on the social dimension if performed at the same time as a study into legal definitions of energy sharing activities (Task 1.1), an inventory of existing energy sharing tools and platforms (Task 1.3) and the formulation of business use cases (Task 1.4). To research the social dimension, we identified the need to have in the first phase of the task a list of activities at hand. Task 1.2 therefore provided input for the development of an initial set of activities by engaging in joint interviews with the pilot managers. In the remainder of this report, the activity list summarized in Table 1.1 and further explained in ANNEX I is used to refer to the specific activities that the individual pilots (plan to) undertake.

Table 1.1: List of energy community activities relevant for the U2Demo project

Activity type	Activity
Energy exchange	Energy sharing via cashback model
	Joint self sub-supply (energy sharing via sub-supply model)
Collective self-consumption registration	Energy sharing via adjusted energy bill model
	Energy sharing via cash-back model or vouchers
Explicit flexibility	Collective self-balancing
	Collective flex activation delivery to a flexibility service provider
Implicit flexibility	kWmax balancing
	Optimization for local sustainability goals
Community services	Not specified
Collective control	Collective control of individually or jointly owned assets
Management and operation of infrastructure	Not specified
Collective ownership	Not specified
Domain transcending value	Not specified

1.3.2 Knowledge transfer to technical development

The main application of this work is within the technical work packages (WP2, WP3, WP4) where the energy sharing architecture, open source platform and sharing algorithms will be developed. By investigating the contexts and motivations of active consumers and the collectives they are part of, these technologies can be aligned with their values and preferences. This will take effect in both the back end of the energy sharing platform (architecture and algorithms) but also the front end (interfacing, user experience). Within the U2Demo project, Task 1.2 will primarily carry over its findings to Task 2.1, responsible for the translation of WP1's insights and framework to the concepts to be developed across the technical work packages. For the development of front-end features, a specific handover will also be delivered to Task 3.5, responsible for user interactions.

1.3.3 Continuation of engagement within the pilot sites

The work in this task requires research that is performed in close collaboration with the pilots and its members. For many members, it will be their first engagement with the U2demo project and the development of energy sharing activities. At the same time, the outcomes of this study aim to suggest directions for the development of energy sharing activities that are appealing to active consumers, boosting engagement. The work of this task therefore translates to the formulation of engagement strategies (Task 6.3) and the activities organised in the pilots where the members are involved (WP5, energy sharing tools demonstration).

2 Background

2.1 Literature review

To provide the research work in this task (Task 1.2) with theoretical grounding, we reviewed works related to the subject of energy sharing in communities. In total, we cover four topics: the values and social dynamics related to energy sharing, the principles of energy allocation and pricing, principles of fairness with regards to the energy sharing process, and the design of interactions within this process. For each topic we provide short summary highlighting the most important takeaways of this review.

2.1.1 Values in energy sharing

As mentioned previously in the introduction, the potential values underlying energy sharing activities are numerous. These values are crucial in energy sharing to define the input used for optimization and final results. First and foremost, energy sharing is a way to optimize (local) energy production in a way that is more efficient, reducing costs and increasing sustainability (Zhou & Lund, 2023). Additionally, a higher energy-efficiency and displacement of energy use at moments throughout the day where peak usage is expected can avoid grid congestion, and, with that, prevent costly infrastructure expansion. Depending on the combination of community members, their assets, consumption patterns and flexibility in displacing their energy usage, significant benefits can be achieved which can manifest into a lower electricity bill for citizens (Neves et al., 2020).

But besides these, somewhat utilitarian benefits that are easily expressed in numbers, the sharing of energy also brings about far-reaching social advantages that are more difficult to materialize. A higher degree of self-consumption from local energy sources can increase the security of energy supply at affordable prices, and making shared use of these new, often costly, energy technologies will make these assets accessible to a wider audience (Interreg Europe, 2018; Wilkins et al., 2020). On top of that, energy sharing is also a social act, aimed at maintaining social relationships with a community of people (Singh et al., 2017; Wilkins et al., 2020; Zhou et al., 2020).

In order to clearly define what motivates the sharing of energy, a division can be made between ‘mutual energy exchanges’, where individuals known to each other share energy within a social and cultural context, and ‘market energy exchanges’ that are executed on a larger market somewhat anonymously and most of all, rooted within principles of rationality and efficiency (Singh et al., 2017). Within the mutual realm, closely related to how energy communities (ECs) are organized, social relationships are the main product of the exchange. These can be formed around various aspects such as kinship, ethnicity, religion, or nationality. Key to these mutual exchanges is the existence of a mutual realm, within the context of homes and local economies. Resulting relationships not only stretch individual connections but also group bonding (Singh et al., 2017).

To include both utilitarian perspectives on energy sharing as well as social value and relationships originating from communal contexts, the outcomes of sharing energy can be dissected into the flow of energy between giver and receiver, the social relation between them and the other values that originate from this exchange (Figure 2.1).

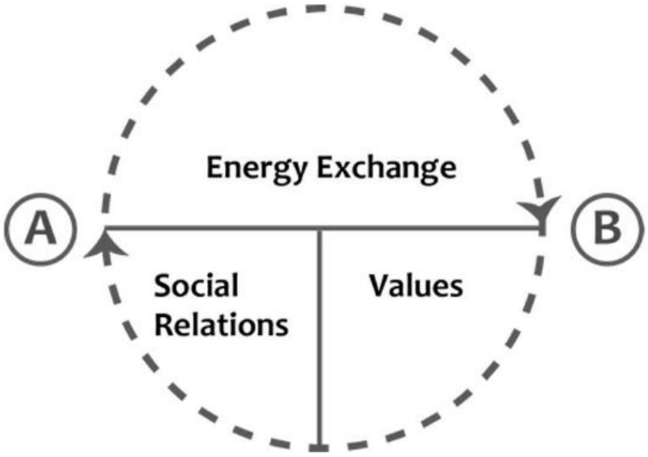


Figure 2.1 – A visual representation of a circle of mutual energy exchange as visualised by Singh et. al. (2017). 'A' is an 'energy-giver' and 'B' is an 'energy-receiver

As opposed to the rational sharing schemes that we will explain further under allocation of energy and pricing models, a mutual sharing scheme actively aims at achieving both monetary and social goals. This is in line with the objective of ECs who do not have monetary gains as their sole proposition. To make this mutual energy sharing a success, special attention needs to be given to existing social relations such as co-dependency, work engagement, and associated trust. Shared ideologies or kinship might also serve as mutual basis for energy sharing in the spirit of like-mindedness. Monetary agreements can even become undesirable in some cultural contexts and within some relations as it can be considered immoral or unethical. It's therefore of utmost importance that mutual energy sharing activities are recognized as such and are not intertwined with sharing by default. Making "circles of energy exchange" such as visualized in Figure 2.1 can be a way to keep sharing activities within their respective cultural and social boundaries (Singh et al., 2017).

2.1.2 Allocation of energy and pricing

For the allocation of energy and the division of costs and monetary benefits, various theories about the distribution of these commodities have been researched and modelled. Many of these theories outline the rules of sharing schemes that can have game-like qualities. Peers that participate in these schemes provide input in the form of preferences and use profiles, hoping for an expected outcome. The final allocation of energy and price of the transaction is determined by the input of the various peers or 'players'.

Generally speaking, two types of allocation theories can be distinguished: auctions and bargaining (Zhou & Lund, 2023). In auction theory, the players place bids, often automated, on energy available. A rational division is then made based on all bids that maximizes certain utilities, such as financial benefits or sustainability gains. Fundamentally, this theory puts players in a competitive position and stimulates them to act in self-interest. The resulting balance of interests in this non-cooperative scheme should strive to achieve a Nash-equilibrium where no players are better off changing their strategy. In the case of bargaining, players take a more cooperative stance and interact with each other to agree on the allocation of energy and pricing. Examples of such pricing schemes include bill sharing, where all peers take a share in the total export and import of energy to the grid, and mid-market rate, where a median price is determined by the feed in tariff and dynamic tariff for buying from the grid (Long et al., 2018). Whilst this method requires more communication between the players, the process inherently ensures that players commit to a strategy and can increase the perceived fairness. For example, a negotiation between players with different incomes could result into pricing that aims to achieve equality (Zhou & Lund, 2023). In some cases, it was found that an equal split of costs and benefits led to a social optimum (Chau et al., 2019).

Whilst these theories each have their respective advantages, no clear view has emerged on what theory results in the greatest outcomes (Chau et al., 2019; Neves et al., 2020), and their application mainly depends on the context (Neves et al., 2020). The availability of flexible loads, types of users, communication channels and community size all influence the extent to which an allocation scheme can achieve utility benefits in a way that also maximizes social welfare. It should be noted that EU regulations steer away from competitive auction theory in favour of bargaining schemes. Consistent throughout both theories, however, is the process of matching peers with their respective energy profiles and preferences in a way that is perceived as fair and results in a coalition that remains stable (Chau et al., 2019; Long et al., 2018; Oh & Son, 2020). Peers must therefore define what outcomes they see as desirable and what they think is fair. Views on this matter can vary greatly within collectives that aim to implement energy sharing activities (Wilkins et al., 2020).

Regardless of the allocation method and pricing scheme, the energy communities that apply this technology on a national grid are likely to communicate with their respective DSO and energy suppliers about the way that resources are distributed. If they don't, allocation of energy on a national scale might become more difficult or less efficient. In both scenarios, this results in higher administrative costs that the involved parties will need to cover with the profits from their scheme (Chau et al., 2019). Besides the development of this business case, the core challenge for the formulation of an allocation and pricing scheme is to organize a decentralized decision-making systems that is able to realize both individual as well as collective goals in a way that respects autonomy and is considered transparent and fair.

2.1.3 Principles of fairness

From the analysis above, it becomes apparent that one of the most important principles for a decentralized energy system is that of fairness. Not only is it important in deciding upon the allocation of energy, costs and benefits, the perceived fairness of sharing also greatly affects the engagement of peers (Zhou & Lund, 2023). Furthermore, a fairer energy system is also considered to be one of the main advantages of such a decentralized energy system over conventional grids.

All such aspects of a fair energy system are expressed in the tenets of energy justice developed by Heffron and McCauley (2014). They describe how a just or fair energy system (1) *distributes* all energy, costs and other value fairly, (2) includes all parties in the entire *procedure* in a way that they are able to participate and stay informed, and (3) *recognizes* all stakes of all parties and their autonomy.

When putting these principles into practice within the design of energy sharing systems, their manifestations can be structured along the lines of diverse values or requirements (Jensen & Jensen, 2023). Table 2.1 presents an overview of these requirements along the three tenets of energy justice.

Table 2.1: Overview of the manifestations of energy justice principles in energy sharing adapted from Jensen & Jensen (2023)

Energy justice tenet	Value or requirement
Distributional	*sustainability* on an environmental, social and economic level (triple bottom line)

Energy justice tenet	Value or requirement
	communal culture through connecting with the community and its history by taking ownership and action
	inclusion by getting all members and stakeholders to participate and taking into account their characteristics
	reliability where new technology can be seen as risky whilst at the same time removing the risk of human error
Procedural	*collaboration* where the community is able to participate in energy sharing activities on equal footing with other actors
	competency where members learn from the activities in the community
	routinization which outlines the importance of aligning existing habits and practices with that of new platforms
	data transparency so that members can understand the (sustainability) impact of their own consumption patterns and acting upon it
Recognition	*aesthetics* by being represented in a way that is both pleasing and respectful to the community and its (historical) image
	autonomy by being able to "pull the plug" and be self-sufficient with regards to resources

Whilst all these aspects are important, the review study of Zhou and Lund (2023) highlights the lack of knowledge on distributional fairness when applied in energy sharing practices. To distribute the gains and costs of energy sharing fairly across the members of the communities, principles developed by the Dutch Scientific council for policy could provide some initial guidance (Hulscher et al., 2023). In their approach to energy justice in the Netherlands, four different perspectives on matters of distribution provide insights into the way that resources can be allocated:

- Result-driven – all resources are allocated in a way that achieves the greatest (sustainability) impact
- Individual rights and freedom – all resources are allocated across individuals. Three approaches are proposed:
    1. Equal division per capita
    2. Division across existing property rights, investments or expectations
    3. Participating at own risk; everyone makes up their own balance
- Solidarity and capacity – the diversity of actors utilized for the greater good. Three approaches are:
    1. Adjusting for capacity (i.e., wealthy citizens profit less/pay more)
    2. Putting those least fortunate first by making sure that their situation does not deteriorate at the least

3. Division with a bottom line; everyone is assured of everything essential to have a decent life

- Earn as you contribute – compensating for individual actions. Three approaches:
    1. Pay per emission; whoever emits the most pays the most
    2. Division based on profit; whoever can profit most will get most
    3. Profit from reductions; whoever reduces more gets more

Many of these examples of distributional justice principles are oriented around achieving a sustainable outcome or financial gain. When applied to energy sharing, other motives such as independence, either as an individual or collective, might provide an additional perspective.

2.1.4 Interactions with energy sharing

In the first chapter we already introduced three touchpoints as part of the research setup. These touchpoints are derived from the overall interaction that peers or households will have with a P2P system. Similarly, other studies outline the phases of interaction between a P2P system and its users (Chau et al., 2019). This interaction starts with a planning and matching phase where data is used to suggest good sharing coalitions that together optimize benefits. This is then followed by an agreement on allocation of energy and costs that will last for a certain timeframe. Afterwards, the agreement will become operational, meaning that peers will be able to monitor and adjust their own behaviour in order to maximise outcomes. After the agreed upon period, these peers will see the effect of their behaviour with regard to the benefits and get the opportunity to renegotiate the terms (Chau et al., 2019).

For all of these touchpoints, peers and their respective communities that make use of energy sharing platforms and tools might have preferences and capacities that greatly affect the design of these products or services. In this section of the literature review we provide an overview of initial works that explore this area of design. We cover aspects of gamification, information provision/dashboarding and physical interactions separately whilst first listing some high-level design requirements.

A first requirement from a high-level perspective tackles the diverse nature of energy communities and the great amount of preferences that can be expressed through energy sharing activities. Platforms should match this diversity by being flexible, allowing for multiple energy sharing activities, goals, governance models and business models (Wilkins et al., 2020). A similar logic holds for preferences that are specific to the allocation process. As the process of allocation is not necessarily top-down or centrally organised, peers might structure this themselves through in-app interactions. In these interfaces, peers can express preferences for the allocation process. Some of these preferences might be predefined (e.g., time of day, price) but 'local constraints' can also arise. A negotiation system should allow for the local constraints to be expressed as well as allow for some ambiguity as some peers might not have a clear preference going into the negotiation process (Chakraborty et al., 2020; Wilkins et al., 2020). In the same spirit, the platform should also be scalable, anticipating growth of the community and allowing for the community to obtain rewards that are only achievable with a greater number of members (Wilkins et al., 2020).

Furthermore, the platform should allow for a variety of consumers and prosumers to join, not excluding anyone based on assets available. Additional effort should be made to include those less knowledgeable about new energy technologies, such as through the availability of educational material or channels (Wilkins et al., 2020). At the same time, inclusion and digital literacy support could stimulate trust in the platform, together with simple and transparent pricing and brand visibility in physical spaces (Wilkins et al., 2020).

2.1.4.1 Gamification

One of the most promising principles for the design of energy sharing is that of gamification. Gamification theory applies knowledge on behavioural change within the field of UX design to urge users to act in line with certain objectives and cement these new behaviours in gameplay routines. By introducing elements of play and fun into interaction with energy platforms, more engagement can be fostered, along with achieving better results in terms of energy efficiency or self-consumption (Nasrollahi et al., 2023). These results can be expressed in points or scores, later to be exchanged for monetary or status rewards.

To make gamification a success in the context of energy systems, the designed game should be simple (avoiding complexity and limiting the number of gamified elements), align rewards properly with performed behaviours, integrate educational content properly and take into account the real-world context in which it is applied (Nasrollahi et al., 2023). In line with earlier findings, the gamification of social value exchanges can be experienced as undesirable or unnatural. At the same time, the exclusion of social gestures in score keeping can lead to users performing fewer of these social acts, even if these are not energy related. Another unintended consequence of badly executed reward schemes is the satisficing of score mechanisms where users only perform behaviours that have a short-term, immediate effect on their reward (Cila et al., 2020). Further common mistakes with gamification schemes are the lack of interaction with operators, failure to include privacy standards and fading engagement levels on the long term (Nasrollahi et al., 2023).

2.1.4.2 Information

A second important aspects of platform and tool design is the provision of information. Various works have already explored the topic of visualizing information about energy use in the light of usage overviews or long-existing interfaces such as thermostats. Froehlich (2009) provides a comprehensive overview of important design aspect for interfaces that aim to displays energy use information (Table 2.2).

Table 2.2: Overview of design aspects essential for designing good feedback systems on energy information (Froehlich, 2009)

#	Design aspect
1	The frequency of updates
2	Units of measurement
3	Data granularity
4	Accessibility/provocativeness of information
5	Medium
6	Location
7	Visual design
8	Action perspective
9	Comparisons with others
10	Social sharing

Further studies that examined various types of visualizations in the context of energy consumption outline the importance the information density, characterized by the spacing of elements and the balance between information and visual elements (Nimbarte et al., 2024). Not only would this improve engagement, but it also increases the perceived trustworthiness. If graphs are used as visual ways of presenting information, they should be somewhat familiar to the audience and not contain too many layers of information (Al-Kababji et al., 2022; Nimbarte et al., 2024).

Few evaluations stretch the design of an interface that provides information on energy sharing specifically, but it is clear that these should concretize the benefits of sharing so that progress can be tracked towards shared goals in the community. Examples are self-consumption rates, total generation, CO2 saved and reduced use of fossil sources. Shared goals in the community can stretch from local to more ideological proportions, which should be reflected in the way that thus information is presented (Wilkins et al., 2020). Furthermore, Jensen & Jensen (2024) ran an explorative study on communicating justice principles in a P2P platform by showing context information, availability of peers and allowing peers to distribute available energy themselves (Jensen & Jensen, 2024).

2.1.4.3 Physical interactions

A final aspect concerns the physicality of the interactions with platforms and tools. Besides the mostly digital, on-screen applications, various Human-Computer Interaction (HCI) projects around new energy technologies, products and services illustrate how tangible interactions with designed objects can provide additional value through the richer UX. Furthermore, interactions in the physical space can heighten accessibility in communities with low digital literacy and more easily encourage social interactions. All of this benefits the engagement of peers (Froehlich, 2009; Wilkins et al., 2020).

2.1.4.4 Trade-offs

When taking all these aspects into consideration, is it inevitable that trade-offs must be made between certain features and the values and preferences they embody. Within literature, we find three crucial value conflicts that must be mediated by the design of energy sharing platforms.

Firstly, a balance must be struck between privacy and transparency. Privacy and security of data handling is of utmost importance to peers to be willing to use the platform. The best way to ensure this is to provide control and ownership of the data for individuals or encrypt the data, such as through blockchain technology. At the same time, this obscures the information from users, negatively impacting transparency. A higher transparency can foster more trust as well as allow users to hold other users accountable for their actions in the case of shared resources. This requires them to make their data available to the community to a certain extent (Cila et al., 2020; Jensen & Jensen, 2024; Wilkins et al., 2020).

Secondly, matters of automation seem to clash with values of control and flexibility. Automation can reduce the amount of effort needed to participate and increase the reliability energy sharing. However, it also counteracts transparency measures and excludes peers who are not proficient in utilizing such digitally adept features. Furthermore, high levels of automation might make it difficult to respond to unique scenarios that were not anticipated (Cila et al., 2020; Jensen & Jensen, 2023; Wilkins et al., 2020).

Lastly, a focus on individual autonomy or local values and interests might stand in the way of involving actors and sectors on a larger scale. The other way around, a focus too much directed towards outside collaboration might come at a cost for communal culture (Jensen & Jensen, 2023).

2.2 Detailed overview of the pilot sites

2.2.1 Portugal – Valverde, Évora

Context

Small community in a countryside town that is working on becoming an official energy community. It was started by energy supplier EDP who approached a group of 10 citizens. They have enrolled in various projects over the years to build their community and acquire assets that make their energy consumption more sustainable.

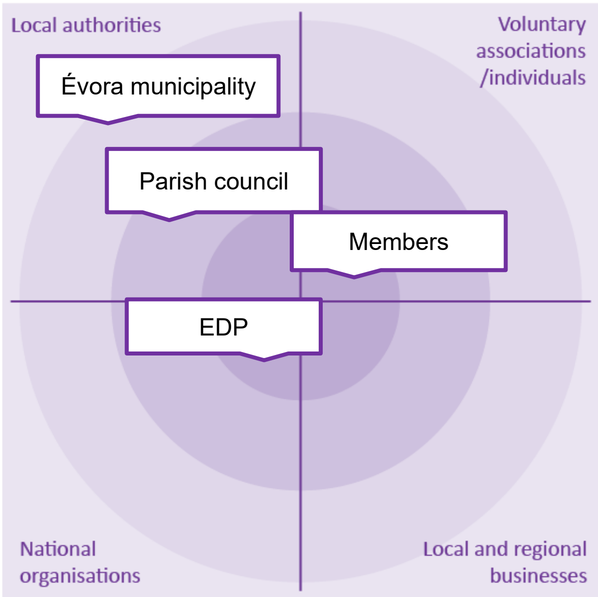
Goals

- Improve on their electricity bill. Currently, feed-in tariffs for solar energy that is not used by members are very low.
- Increase the amount of self-consumption
- Acquire more assets and include more households on the long term to grow the community

Activities

- Energy sharing via adjusted energy bill model
- Energy sharing via cash-back model or vouchers
- Collective control of individually or jointly owned assets

Involved parties



Assets & Infrastructure

- Each house is equipped with 1,5kW of PV
- No source of wind
- Each household has a 10 kWh battery
- Most households have electric heating and cooling
- One household own an electric vehicle
- Most houses are fully electric, including stoves

2.2.2 Italy – Vallevignale

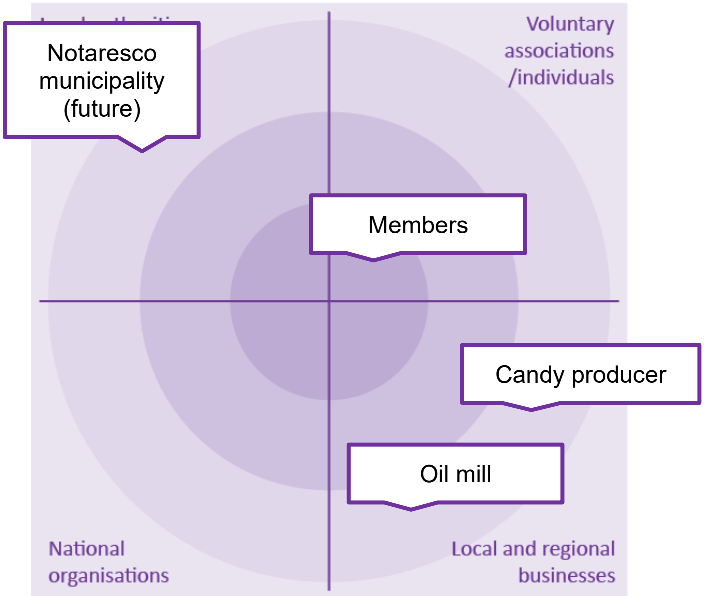
Context

Small town in the countryside which consists of 20 buildings, around 60 people, a candy factory and an olive oil mill. They are an official energy community since 2021 with 10 members. It was initiated by a few innovative inhabitants and is now governed by a board of 5 members. They mainly strive to be more independent.

Goals

- To become more independent and ensure a stable energy supply, also in terms of costs
- Grow the community and re-invest in public facilities
- Build a better data and metering infrastructure

Involved parties



Activities

- Energy sharing via cashback model

Assets & Infrastructure

- In total, the houses have 42kW of PV installed
- There is 105 kWh of battery storage installed
- The community features 7 EV chargers and EVs
- There is no source of wind energy
- Some of the buildings have air conditioning and 5 have heat pumps
- No other assets

2.2.3 Belgium – Mechelen

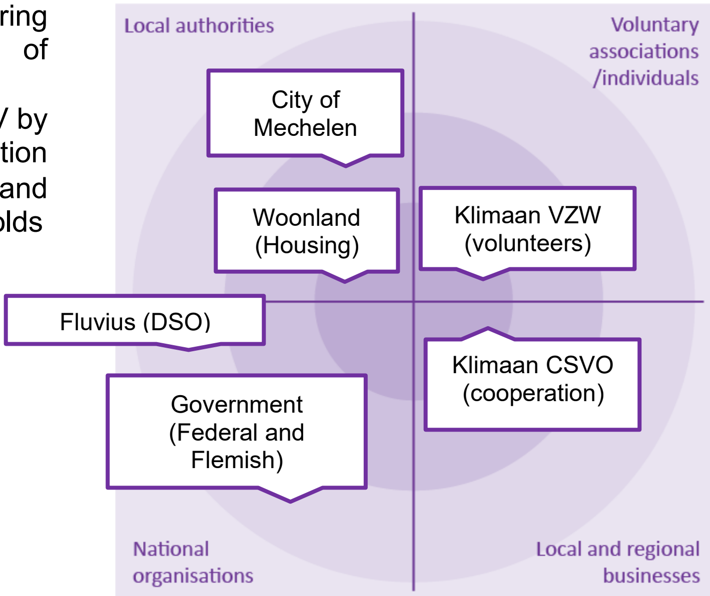
Context

Cooperation Klimaan has used investments from Mechelen's citizens to install solar panels in the social housing suburb Otterbeek, in the North of Mechelen. They have connected 197 families to a supply of sustainable energy this way, lowering their energy bills at the same time. They also provide various other communal services such as rental EVs and social events.

Goals

- Find a way to make energy sharing profitable, lowering the price of administration
- Make better use of the installed PV by increasing collective self-consumption
- Make energy more sustainable and affordable for low-income households

Involved parties



Activities

- Energy sharing via adjusted bill model
- Collective kW-max

Assets & Infrastructure

Across various panels, there is 2MW of installed PV

Plans to install some small batteries in Otterbeek houses

Plans for a public charging hub in Otterbeek

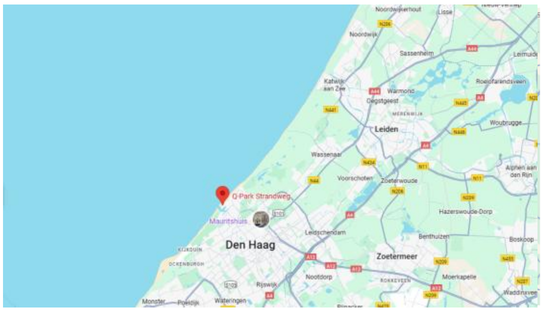
There is no source of wind energy

No electric heating or cooling

No other assets

2.2.4 The Netherlands – Scheveningen

Context

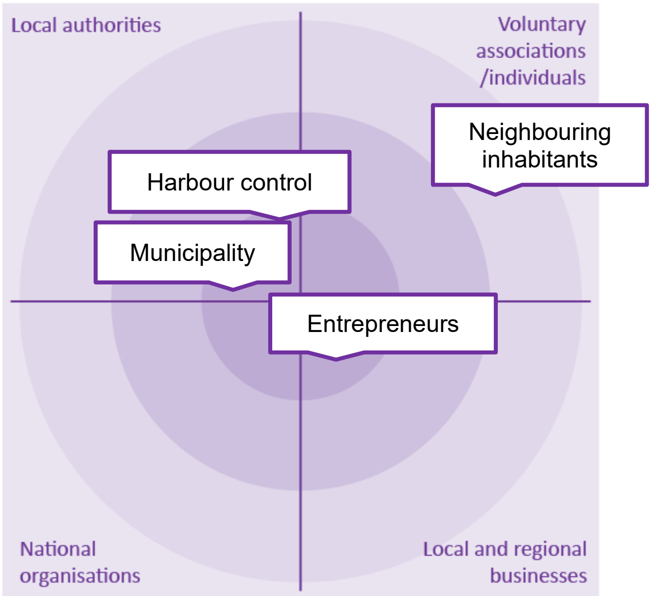


At the end of the promenade of Scheveningen, the beach side of The Hague, lies a unique part of the energy grid. Here, the municipality has created the opportunity for local entrepreneurs to innovate and build towards an efficient and sustainable energy system. Together with the harbor control, 3 entrepreneurs have started an energy community within this pilot.

Goals

- To use as much of the locally generated energy as possible
- To offer flexibility and load balancing on large scale markets
- To solve congestion issues and be more sustainable

Involved parties



Activities

- Collective kW-max
- Collective flex activation delivery to a flexibility service provider
- Collective self-balancing
- Energy sharing via day-ahead self-sub-supply
- Optimization for local sustainability goals
- Community control

Assets & Infrastructure

Total of 8kW of PV installed

They lease a 250kWh battery

The harbor control has EV cars for patrols and chargers

Plans for a windmill

Some of the buildings have electric heating, plans for more

There are high capacity outlets that supple ships with electricity

3 Methods

This chapter describes the research method used in the empirical part of the study. The study involved conducting semi-structured interviews on-site at the pilot locations. These interviews were held in the local language or supported by relatives of the interviewees who could act as translators. This enabled participants from the various pilot sites to speak freely and get clear explanations about the concept of energy sharing. Interviews lasted between 1 and 1,5 hours in total, covering the various aspects of energy sharing relevant for the development of energy sharing platforms and tools. The resulting insights are presented in this deliverable and serve as input for the development of such platforms and tools within the pilot sites.

3.1 Interview setup

The interviews were conducted by project partners located near the pilot sites who were fluent in the local language. In the case of Portugal, EUI and EDP conducted the interviews. EUI and EnGreen conducted the interviews in Italy, and TNO conducted the interviews in Belgium and the Netherlands. All interviews were conducted in pairs of two, one researcher leading the interview and the other taking notes. Except for The Netherlands, all interviews were scheduled during day-long visits to the pilot sites. Due to its proximity to TNO offices, multiple trips were made to the Dutch pilot. All interviews were held at the homes or businesses of the participants.

The interviews covered three main topics which were grounded in literature. Besides a short introduction about the participant and their relation to the community, the interviews consisted of a first part addressing current knowledge on energy use, energy sharing and general intentions to take part in this activity. Following these questions, we asked participants to indicate for a predefined selection of sharing circles (based on pilot specifics) whether they would like to share energy, whether they would adjust their own use patterns, how they prefer energy, costs and profits to be allocated and what they think is a fair way to do this. To aid the conversation with respect to principles of fairness, the distributional principles explained in Chapter 2.1.3 are introduced as guidance. In a final series of questions, we asked participants about their preferences and capabilities with regards to the three touchpoints with the energy sharing platform and tools that were defined in the introduction. Amongst these questions were unique questions per pilot site that correspond with the specific development goals of these pilots. Adding to this final section are also questions about the trade-offs mentioned in the previous chapter. In these trade-offs, essential matters of transparency, privacy, autonomy and control are discussed. An example of one of the interview guides can be found in APPENDIX A: Interview guide (EN).

3.2 Participants

For each pilot site, we recruited participants through the network of the corresponding pilot leader. The total sample of participants is representative for the each of the pilots and is further characterized by an equal distribution of genders. We provide a short overview of the recruitment effort for each pilot:

- Portugal – EDP maintains close contact with all members and approached them for interviews by phone. From the 5 members, 3 were able and willing to take part in the study as well as a tenant that lived in the same building of one of the members. All participants are listed in Table 3.1.

Table 3.1: Overview of Portuguese participants

Participants PT		
Role in Community	Gender	Reference
Inhabitant/member	Female	PT1
Inhabitant/member	Female	PT2
Inhabitant/tenant of PT2	Female	PT3
Inhabitant/member	Male	PT4

- Italy – EnGreen acted as intermediary for this energy community and approached them for taking part in the study. 5 out of the 10 members of the community were recruited, they are listed in Table 3.2.

Table 3.2: Overview of Italian participants

Participants IT		
Role in Community	Gender	Reference
Inhabitant/Initiator	Male	IT1
Inhabitant/member	Male	IT2
Inhabitant/member	Female	IT3
Inhabitant/member	Male	IT4
Inhabitant/member	Female	IT5

- Belgium – Klimaan took initiative in recruiting participants for the study. They went door-to-door with flyers and approached tenants in person, explaining the U2Demo project. Besides recruiting in Otterbeek, the suburb where they installed solar panels, they also recruited participants from a neighbouring social housing area (“Oud Oefenplein”) that currently have no access to sustainable energy and or not yet members of Klimaan. Besides their lack of experience with Klimaan and the use of solar panels, these tenants are very similar to the inhabitants of Otterbeek in terms of capacities and (cultural) background. As incentive to participate, they offered to cover administrative costs of energy sharing for a year. From the 197 households, 1 participant was recruited in Otterbeek and another 6 from all households in the neighbouring suburb. All participants are listed in Table 3.3.

Table 3.3: Overview of Belgian participants

Participants BE		
Role in Community	Gender	Reference
Tenant Oud Oefenplein (no PV)	Male	BE1
Tenant Oud Oefenplein (no PV)	Male	BE2
Tenant Oud Oefenplein (no PV)	Female	BE3
Tenant Oud Oefenplein (no PV)	Male	BE4
Tenant Otterbeek (PV installed)	Female	BE5
Tenant Oud Oefenplein (no PV)	Female	BE6
Tenant Oud Oefenplein (no PV)	Female	BE7

- The Netherlands – TNO obtained the email contacts of the members in the pilot through the municipality of The Hague after the project was announced at the general assembly of members. All members took part in the study with the exception of one entrepreneur who was still in the process of building their business. In line with ambitions to include neighbouring citizens in the future, 2 inhabitants were recruited through the existing network of the community members (Table 3.4).

Table 3.4: Overview of Dutch participants

Participants NL		
Role in Community	Gender	Reference
Inhabitant (Possible future member)	Male	NL1
Inhabitant (Possible future member)	Male	NL2
Representative harbour control/member	Male	NL3
Entrepreneur/member	Male	NL4
Entrepreneur/member	Female	NL5

3.3 Data processing

All interview notes were made in the local language and later translated into English. This was done with the help of audio recordings made during the interviews. Findings were derived from these notes within a thematic analysis (Braun & Clarke, 2006) in whiteboard software Miro. In this analysis, we clustered these findings along seven themes: *Community and relations*, *Energy profile*, *Knowledge, capacities and interfacing*, *Motivations and values, Distribution and sharing circle*, *Financial* and *Governance.* These clusters were made for each pilot by TNO together with the interviewers for the specific pilots to ensure that all findings were correctly processed. In a final analysis, the clusters from the various pilots were combined by looking at similarities and differences with regards to the same seven topics.

3.4 Ethics

All research activities were performed in line with European regulations. All participants signed consent forms and were informed of the implications of taking part in the study. All data were anonymized, and audio recordings were retained for no longer than 3 months. The entire research procedure was reviewed and approved by the ethics committee of TNO prior to the study.

4 Results from pilot interviews

In this chapter, we describe al findings from the interviews along the seven categories used in the thematic analysis. These findings mainly cover generalised input on a pilot level and detailed example on a participant level. In all pilots except the Belgian pilot, we refer to the participants as members of the communities. In the case of Belgium, we use inhabitants given that they have yet to become official members. All remarks or insights that originate from specific individuals or groups are labelled with the corresponding participant reference [XX#].

4.1 Portugal – Valverde

4.1.1 Community and relations

Findings from the Portuguese pilot show that community members have deep connections at the pilot sites. Most of them are Portuguese citizens who have lived in Valverde for decades, with some having resided in the same community since childhood, and their parents having lived in the same house in the past. Others moved to the community after marriage and have been residents ever since. Some members described the inhabitants of Valverde as 'members of the family' [PT1], but those who are part of the energy community are acquaintances. One member joined the community after receiving positive recommendations from a neighbour [PT2]. In general, Valverde is a parish council with a major elder population.

4.1.2 Energy profile

In terms of the energy profile, inhabitants' awareness of their energy consumption is limited to a reference to the overall electricity bill. The monthly bill typically ranges from 100 to 150 EUR, increasing during winter to as much as 300 EUR [PT1]. All interviewed members have electrified households; in other words, they are no longer connected to the natural gas network. This means they have several flexible assets such as electrical heating and cooling systems, electric boilers, and an electric stove. All members of the community have installed PV panels, and one of them has also installed a battery and an EV, which they charge it mostly at home. Valverde is a parish council that functions as a residential area, with most of its residents working in the centre of Évora, which is 12km distant from Valverde. Therefore, their electricity consumption mainly occurs in the evenings.

4.1.3 Knowledge, capacities and interfacing

Community members have limited understanding of how energy systems work. As previously mentioned, their reference to energy consumption is only to the total cost of the electricity bill. Members have reported a positive view of increased energy savings after joining the energy community, with one member even paying 40% less [PT1]. Besides these savings, community members cannot distinguish between the amount of electricity generated by the installed solar panels, self-consumed within the community, and shared with the electricity grid, and have little understanding of how the electricity grid functions. In one case, a member could barely recall where the energy meter was located in the house. If an app were available to provide information, all of them expressed interest in having access to more information about the volume of electricity consumption, in terms of the volume self-generated, self-consumed and shared with other community members. One of them would also like to understand the generation capacity better - whether the solar panels are producing more or less than their own consumption [PT4]. Others request more specific information about the battery optimisation level. All members have an interest in receiving information to optimise savings, such as better demand response for appliance use. Despite their interest of receiving more information, the members' capacities to make use of such apps are quite diverse. While some have little experience only with basic retail consumption apps [PT1, PT4], others are familiar and have used more advanced apps used in different project – Integrid[3] - allowing to check whether the residence was using battery or solar energy, as well as electric vehicle charging apps [PT2].

4.1.4 Motivation and values

When asked about their motivation, the primary purpose mentioned by the members is the financial benefits coming from reducing costs of the electricity bill. While some feel more optimistic about the potential economic benefits for selling energy, others are less optimistic of receiving financial gains and expressed concerns about the costs of the PV maintenance. The second motivation referred to in the interview is the possibility of being self-sufficient, namely, independent from receiving grid electricity. It is worth noting that the interviews occurred four days after a major blackout that impacted Portugal and Spain on 28 April 2025, which lasted for approximately twelve hours. The community members were surprised that their electricity was cut off, despite the installation of PVs and, in one case, battery assets. Thus, the extreme event of a blackout could have affected their value perception of being self-sufficient. Whether this newly adopted view sustains remains to be seen. The third motivation was referred to as a common good, emphasising the importance of involving people in increasing renewable generation. There has been a reference to the extent of trust. Whereas there was mistrust in community projects in the past, after some members reported financial benefits, there has been an increase in interest. Lastly, all interviewed members also expressed concerns about the risks of bidding conflicts, where community inhabitants could choose to whom they share or sell for which price, and this could become a source of conflict. They would prefer an autonomous and anonymous system for sharing or selling energy.

4.1.5 Distribution and sharing circle

Regarding the sharing circle, there is a strong preference for restricting it to locals, specifically inhabitants of the parish council of Valverde. One of the members would consider sharing energy with nearby municipalities. However, all of them reacted negatively to the proposal of sharing energy within a national system. In reality, Portuguese regulation limits sharing on low-voltage grids to 2km, creating another barrier to sharing energy on a larger scale. As for the distribution of benefits, there exist diverse interests. While most of them agree with a proportional distribution of benefits – i.e., who produces and shares more must receive more benefits -, others also consider social benefits as sharing with elders, lower-income inhabitants, or vulnerable consumers.

4.1.6 Financial

In case any financial gains are made, personal benefits are preferred by the members, even acknowledging that these benefits have a small margin. Only when asked whether they would

[3] https://cordis.europa.eu/project/id/731268

consider reinvesting the financial benefits in the community, some mentioned the possibility of investing in energy assets for the community, such as additional batteries and photovoltaic (PV) systems. In contrast, others suggested investing in community goods, like a playground. Concerning the sharing of fees, community members favour the application of the user-pays principle, in other words, fees must be paid for those who buy/receive energy, not those who generate and inject energy into the grid.

4.1.7 Governance

In terms of governance, members prefer a direct vote system, in which each member has the right to one vote within the community. The decisions could be deliberate in meetings organised seasonally, being more frequent at the beginning and evolving to meetings twice a year. One member recommended training sessions about sharing funds and to ensure a more informed decision-making process [PT4].

4.2 Vallevignale

4.2.1 Community and relations

Findings form the Italian pilot show that renewable energy community members all know each other. During interviews, they often described their relations as familiar, emphasizing the long-standing roots of the community. Some of them are relatives, others close friends, and many grew up together in the same area. Because of these close relations, members find it quite easy to make their own arrangements related to the energy community, such as organising themselves to take turns to recharge their electric vehicles [IT1]. Some members stressed concerns about the high rate of population ageing and depopulation of the area [IT1, IT3, IT5]. Moreover, they showed varying levels of interest in each other's energy consumption: some are more informed, while others are less engaged.

4.2.2 Energy Profile

Regarding energy profiles, members consider their energy consumption to be average [IT5]. Their energy use varies widely (day/night and summer/winter) depending on lifestyle – some are retired, others spend the day away for work, and one participant joined the renewable energy community with the building where his professional office is based [IT4]. Most have solar panels and electric vehicles, some also batteries [IT2] or electric heating/cooling [IT1], all privately owned. In some cases, members produce excess energy; in others, production does not exceed consumption. They are flexible in adjusting their daily energy habits to meet the needs of other community members. So far, this led to them making a profit on the total energy costs through higher self-consumption. The only exception to this flexibility might be heating, as participant considered it essential that this should not be altered [IT1]. Members see strategic value in collectively charging their EVs and eventually, in future, providing flexibility services to the grid.

4.2.3 Knowledge, capacities and interfacing

Most participants lack technical knowledge of energy system operations. However, they perceive the concept of energy sharing as simple: *'Today I produce, you don't; you consume my energy and we both save money'* [IT4]. Due to their lack of expertise, they are comfortable delegating technical and administrative issues to the community manager, whom they fully trust. The idea of handling these aspects themselves is seen as a disincentive or obstacle. Moreover, because of the peculiarities of the Italian system for calculating, registering and settling results of the energy produced, self-consumed, and shared (e.g. the GSE cashback system, see ANNEX I), community members receive economic benefits only after the first year of operation. In this regard, they would prefer to see this information directly reflected in their main energy bill.

When asked about a monitoring app for the energy community, members expressed interest in features that deliver concrete, timely and personalised advice. Such an app would help them remain fully aware (and in control) of energy production, self-consumption, and sharing, and to receive relevant updates.

4.2.4 Motivations

The interviews revealed that participants' main reason for joining the energy community is to optimise energy costs and save money. Additionally, all members expressed strong interest in the growth of the local community where the energy community is based, eventually expanding its perimeter to surrounding areas, and also applying best practices from the private to the public sector [IT1]. Other motivations and values include increasing energy self-sufficiency and providing a contribution to the environmental and energy transition. Finally, one participant expressed concern about the risk of interference from larger market players and traditional energy suppliers [IT4].

4.2.5 Distribution and sharing circle

When asked about preferred sharing circles, almost all participants favoured sharing energy within the smallest circle – the energy community itself. Looking ahead, they are open to sharing with nearby districts, municipalities, or even the national grid. For economic benefit allocation, they prefer a proportional system that rewards higher initial investments, but also virtuous behaviours (e.g., efficient production and consumption, flexibility in habits). Some members also emphasised the importance of allocating profits to the most vulnerable and disadvantaged members [IT1, IT5]. With regards to sharing data, some members are in favour of sharing any data that is relevant for the good of the community [IT3, IT5]; others are in favour of data sharing with other members only if it is mutual [IT2]; others would prefer providing a specific justification for accessing the other members' data (e.g. not just curiosity) [IT4].

4.2.6 Financial

Members unanimously support reinvesting financial gains into community-beneficial initiatives, especially social services for children and seniors (e.g. electric school buses, tax discount vouchers, playgrounds). They do not prioritise individual financial gain but instead prefer community reinvestment. One member suggested installing e-bike charging stations to develop touristic opportunities to enhance the area around the energy community, given the existence of mountain biking routes [IT4], while another suggested investing in new PV panels on private houses or municipal roofs [IT1]. Regarding the fee/payment for shared energy, most participants preferred individual direct payments and only one expressed their direct preference for vouchers over money as it would undermine energy sharing values [IT4]. Building on that, the community manager reflects on their experiences as running a business [IT1]. The community has to make payments in advance that need to be earned back in the end and decide together on how to distribute potential profits at the end of the year. Most of the time, a balance is struck between individual payouts and investments in the community.

4.2.7 Governance

All members prefer collective and democratic decision-making within the energy community. Currently, this is done informally through in person conversations and a yearly meeting where decision are made together. They are aware of potential conflicts if unwilling members are involved in decision-making [IT3]. One participant expressed concerns about stressful administrative tasks similar to those in condominium management. Members value that the community manager handles technical and administrative aspects and trust him to do so. They suggest that collective decisions can be made quarterly or whenever necessary.

4.3 Belgium – Mechelen

4.3.1 Community and relations

Findings in the Belgian pilot show how this pilot site is characterized strongly by its inhabitants. With many being first generation immigrants, they came to seek refuge or to find a greener pasture and have moved around a lot as they were assigned houses. So-called 'pleinmakers' organize many social activities and people are on friendly terms with each other [BE5]. Language barriers do make it hard to communicate and groups have formed around shared cultural backgrounds or with relatives close by [BE2, BE6]. Inhabitants outside of Otterbeek are not aware of Klimaan and its sustainability efforts and rarely talk with neighbours about their energy use.

4.3.2 Energy profile

In terms of energy profiles, inhabitants did not know how much energy they used but monthly costs vary greatly, partly due to the fact that some inhabitants get a reduced 'social tariff' for energy use. Most energy-intensive appliances use gas, with the exception of an electrical stove [BE3]. Of the electrical assets, only the washing machines and dryers can be considered flexible. Most energy use occurs in the evening and weekends with little changes in electricity use between seasons, except for the time when people cook [BE3, BE6]. Inhabitants are eager to implement changes in their use patterns if it helps to save on their bills and have already adopted various energy-saving behaviours, some unplug all appliances when not in use [BE2, BE4, BE7], either to save on energy or because they perceive the devise to be a fire hazard. The greatest opportunities for load shifting appear to be washing during sunny hours or large meal preparations in the weekends.

4.3.3 Knowledge, capacities and interfacing

As mentioned, inhabitants were generally unaware of their total consumption and were in need of an introduction to the concept of energy sharing and the energy community. When prompted, they indicated they only get a yearly overview of energy used. Feedback is so scarce, that an inhabitant of Otterbeek with solar panels found themselves looking at their energy meter when the sun was shining to see if they worked [BE5]. To inform concrete actions and changes in use patterns, they required more timely information about usage of individual appliances that enable them to be proactive. At the moment, inhabitants rely on gut feeling and rules of thumb learned along the way but were unable to indicate whether these are actually true [BE5, BE6]. For example, heavy appliances were used when neighbours were not at home and one inhabitant did her drying at a local dry cleaner as it was believed to be cheaper than paying for electricity. Some conceptions about the energy grid such as the safety concerns stem from their home country and do not apply to the grid in Belgium [BE3].

Most inhabitants thought it would be fine to receive information through digital means as letters often get lost and digital tools could provide higher accessibility through language choices. Younger relatives were around in most cases to help with digitally adept features [BE3, BE4, BE6, BE7]. Automation could be desirable, most inhabitants would not like payments to be automated. They want to be in control of their payments by personally making the payment monthly. Proposed interactions with others through gamified features or comparisons with others were met with mixed responses and were not considered a priority [BE5, BE7].

4.3.4 Motivations

When asked about their motivations, it was clear that these inhabitants oftentimes need to make ends meet and are primarily drawn in by potential savings. Despite this fact, they see a lot of value in making a contribution to a greater good and place high importance on helping others. As these inhabitants need to play close attention to the amount of money they spend, they also highly value their autonomy when it comes to payments.

4.3.5 Distribution and sharing circle

With the exception of one inhabitant who preferred to share with direct relatives [BE4], there was no limitation to the circle of people that inhabitants want to share energy with. When it comes to sharing data however, inhabitants were more cautious and preferred to keep their consumption data to themselves or only share it anonymously [BE5, BE6, BE7]. With regards to the distribution of energy amongst the peers in this circle, inhabitants prefer an equal distribution to start with but would like to reward those who change their use pattern to suit the production.

4.3.6 Financial

If any financial gains are made through the sharing of energy, inhabitants would prefer to get some personal payout before reinvesting in the expansion of assets. A combination of both would be desirable in order to receive bigger benefits later on. It is imperative for these inhabitants that they will not make a loss at any stage of the implementation of energy sharing.

4.3.7 Governance

Inhabitants might express their values and preferences in future meetings organised by Klimaan as they are currently not part of their community. Inhabitants were open to contribute to such meetings sporadically but required Klimaan to act as an expert and initiator as they lack the knowledge, skills and time [BE5, BE6, BE7]. In addition to that, the inhabitants are renters and do not own the solar installations, meaning that they do not always have an influence on decisions made [BE5].

4.4 The Netherlands – Scheveningen

This section presents the results of the Dutch pilot interviews, focussing on the participants who are current members of the community (NL3-5). Information retrieved from the exploratory interviews with prospective members that live in the neighbouring suburb are addressed in a short summary at the end.

4.4.1 Community and relations

The unique makeup of this community brings both opportunities as well as challenges. At the start, members worried about tension between the intentions of all participants, as some of the involved parties have a competing commercial interest and the municipality has a non-commercial interest. Over time, however, trust between the parties has grown, fuelled by their shared passion for innovation. In practice, the conversations between members are positive and friendly and the entrepreneurs try to focus on their own unique clientele.

4.4.2 Energy profile

The energy use of the members differs greatly as their businesses vary in size. The building of the harbour control is most influential as their operation supplies large ships and runs a lot of monitoring devices to oversee most of The Hague's vital infrastructure. Additional energy heavy assets are heating systems of the buildings, electric vehicles for patrols, (restaurant) kitchens and fridges. Ownership of assets is mostly individual, with the exception of the leased battery that is currently being paid for by the municipality. Besides these individual investments in sustainable assets, the members also implement a sustainable mindset in the entirety of their operations. Buildings are constructed around principles of circularity [NL4], surfers are provided with water saving showerheads [NL5] and EV patrols are run optimally by aligning charging schedules [NL3]. Still, the amount of flexibility amongst the members might be limited. For both the harbour control and entrepreneurs, it is paramount that the service they offer and responsibilities they have are not compromised. In practice, this means that use patterns are highly influenced by daily rush hours [NL3] and sunny weather [NL4, NL5].

4.4.3 Knowledge, capacities and interfacing

Members of this pilot are savvy and go-getters, with some taking up a pioneering role in running their business as sustainable as possible [NL4]. With this attitude, they have been able to learn a lot from the experts involved in the Slim Strandnet[4] project. Monthly meetings where they make sense of metering data together with them have advanced their understanding of the energy system and energy sharing tremendously.

Along with that, some of the members already make use of dashboarding tools developed in the Slim Strandnet project [NL4, NL5] and one of these has even set up their own automated energy management system with Smappee[5], a modular energy management tool with dashboarding and IoT capabilities [NL4]. For others this is not feasible yet as their appliances do not support automation and they need to depreciate first before they can be replaced [NL5]. Furthermore, there is a need for the dashboards to include more detailed data about specific assets. When looking at data from the dashboards, members indicate to prioritize information about costs [NL3, NL4] and prefer visual presentations of the information provided [NL4].

4.4.4 Motivations

Whilst the members have a shared value in their ambition to innovate and be more sustainable, they each have important personal stakes as well. Security of supply is of incredible importance, especially for the harbour control who must stay in operation to prevent vital infrastructure shutting down. To prepare for this, they also have backup facilities that enable them to carry out 80% of their operations in case of emergencies. Also for entrepreneurs, who in some cases have up to 80 employees that depend on them for their monthly salary, a healthy and stable business takes precedence over sustainable ambitions. In order to realise both,

[4] Slim Strandnet – Smart City Den Haag – Digitale innovatie en smart city
[5] Smappee | Designed to Empower

they continuously balance values of comfort (for guests as well as employees) with costs and sustainability impact. To illustrate, temperature control in buildings can be a great way to save costs and energy but as employers, members want to create an agreeable temperature for their employees and hospitality businesses want their guests to enjoy a comfortable space. For one member [NL4], autonomy is also valued greatly, expressed in their desire for decentralized systems, giving each member or visitor of Slim Strandnet the ability to make their own decisions and a preference for privately owned assets.

4.4.5 Distribution and sharing circle

With regards to the distribution of energy, the members have a pragmatic attitude. Although they do not exclude anyone to take part in the sharing of energy by default, their approach can be summarized in two principles: priority for local usage and including everyone with sustainable intentions. This means that they prefer to maintain a small sharing circle as this is the best way to prevent congestion. Other parties, such as inhabitant of surrounding suburbs, can join, but only if there is still energy unallocated amongst the core members and these inhabitants will not 'waste' energy aimlessly [NL5]. From a security perspective, it is important that data does is not shared outside the community and future members are screened to make sure they can be trusted with this sensitive data [NL3].

4.4.6 Financial

In the light of running a healthy business, any financial take on energy sharing in this pilot starts with getting the administration in order. Members are willing to invest up to a certain amount but cannot make losses in the long run. So far, the project and has been backed by the municipality as part of an innovation study but soon this funding will be dialled back. This is expected to make agreements about investments more tense [NL3] and doubts exist about the future of the community with regards to this financial independence. When this fundament is there, extra benefits can be reinvested to serve shared goals of sustainability and innovation. This would go hand in hand with helping those who are not able to make investments themselves, as this is perceived to be the most sustainable from a collective viewpoint [NL4].

4.4.7 Governance

In this pilot, both the municipality and the entrepreneurs are seen as the core members and therefore have an equal say in the votes that are held during monthly general members meetings, this is documented in their legal structure. These meetings are perceived as very positive by all and the attendance of various experts to aid discussion is seen as a big part of that. They are being helped by a lawyer specialized in the field of energy, project coordinators and various technical experts that help with the realization of both infrastructure as well as software solutions. The general perception is that the big challenges for running the community have yet to present themselves when the municipality draws back. Further challenges to governing the community are the introduction of citizens into the community [NL5] and changes to its core members as the local hospitality businesses switch owners frequently [NL4].

Supplementary interviews with potential future members from surrounding area (NL1+NL2)

In two interviews with inhabitants of the suburb Scheveningen, participants described a strong sense of community and a shared passion for the sea, as well as active involvement in local sustainability initiatives such as communal composting and informal discussions about improving the neighbourhood's electricity system. Many residents have already invested in solar panels and electric vehicles, and are gradually transitioning away from gas-powered appliances by enhancing home insulation and adopting smart EV charging. Despite working in the energy sector and being highly knowledgeable, the interviewees noted a lack of detailed insight into their own energy consumption and production, highlighting the need for better information infrastructure. Their motivations align closely with the core values of energy sharing, but they expressed frustration with current tax regulations, which they feel hinder grassroots innovation. The interviewees advocated for keeping energy and any resulting profits within the local community, ideally reinvesting in the area or supporting households unable to make such investments themselves. They also favoured a break-even pricing model based on levelized costs and preferred that community participation remain voluntary, with key decisions handled informally but supported by legal agreements when required.

5 Social requirements and guidelines for Energy Sharing

In this chapter we combine all results from the interviews with pilot members to derive implications for the development of IT architecture, sharing algorithms and user experience (UX) design. We first synthesize findings that relate to core elements of energy sharing that primarily feed into architecture and algorithms (back end). In the second section, insights related to UX design are presented. Both sections contain a general overview of design requirements presented in a table, followed by a synthesis of the findings that underpin them.

5.1 Core principles for Energy Sharing

In this study we split the requirements across two sub-sections: core principles and design requirements for energy sharing. This division aligns with the structuring of the interviews as well as the various layers present in the technology (core architecture and front end). In this first sub-section of the synthesis, we cover the core principles. As introduced in the first touchpoint *setting up for energy sharing activities*, the requirements listed under this section describe agreements between the members of the communities that shape the very fundament of the activities they will undertake. These can be roughly delineated in the governance structure, sharing circles and allocation scheme. Together, the principles should encompass the parties that should/can be involved in energy sharing, their inter-relations, preferences for optimization algorithms and matters of procedural and distributional fairness (research questions 1, 2 and 3). Ideas about dealing with energy poverty are also discussed within the principles for fair distribution. An overview of all the requirement coming forth from the core principles is presented in Table 5.1 followed by a detailed description of the analysis.

Table 5.1: Overview of requirements related to core principles of energy sharing

Requirement type	Pilot	Requirement description
Sharing parties	IT+PT	Members prefer to share only with the community or with surrounding municipalities.
	BE+NL	Members are fine with including anyone in the sharing activities as long as they share the goals of the community.
Sharing circle priority	All	Members agree on a rhetoric of ‘smallest circle first’; core members should get priority over other local parties, who should get priority over others attached to the national grid. Owners of assets always have priority over all others.
Energy distribution (distributional fairness)	All	Members agree on a rhetoric of ‘equal opportunity’; all can make use of the surplus of energy equally. Priority is only given to individuals once all demands of others are met.
Pricing	PT, IT, NL	Members are undecided at this time in the development, additional discussion with the pilots is needed to arrive at a final pricing scheme. It is certain however that the pricing scheme should align with preferences for profit distribution (below) and pilot specific expenses.
	BE	Members would like to keep the price to a minimum. Currently, there is a fixed price at 80% of a reduced ‘social tariff’ or 0,20 cent per kWh (in line with Flanders’ legislation).

Requirement type	Pilot	Requirement description
Profits distribution	PT, NL, BE	Members are undecided at this time in the development, additional discussion with the pilots is needed. The Italian pilot provides a workable example below.
	IT	Members are happy with the current approach. Each year, after expenses, profits are allocated across consumers, producers, cases of energy poverty and community investments. They decide together on what ratios.
Decision-making (procedural fairness)	PT, IT	All members of the community would like to have a vote on important decisions.
	NL	The municipality and the entrepreneurs would like to have an equal vote in important decisions. They prefer that future members that live in the area will not have a direct influence.
	BE	Participants enlisted for the energy sharing would like to be involved in future decision-making. This can follow the example of Otterbeek tenants where members are able to voice concerns and preferences during information sessions and decisions are then made by the board of Klimaan.
Organisational structure	All	Members would like to delegate day-to-day decisions to an informed individual or board (i.e., community manager). We deem it important that legal, social and technical experts advise them. The U2Demo project could provide this.
Meeting structure	All	Members prefer to assemble roughly every 6 months on non-working days to discuss important matters. We observe that it is advisable that experts from the U2Demo project attend based upon the discussion topic.

5.1.1 Sharing circles

Across the pilot sites, differing attitudes seem to emerge when it comes to the sharing circle. The members of the pilot sites don't all object to the idea of a larger amount involved parties, contrary to hypotheses that say that larger sharing circles might lack a mutual basis from which a bond of trust between the sharing parties can be initiated. In the Italian pilot, where two members are sceptical about the intention of outside parties, sharing with local parties seems more appropriate and the same can be said for the Portuguese pilot where members frown upon the idea of sharing energy on a national scale. They believe that this would go against communal values as it is only a financial transaction. In the Dutch and Belgian pilots, members seem to embrace all who share their goals and might contribute effectively to the energy sharing system. In these cases, the values achieved by sharing energy serve as a fundament strong enough to enter in a relationship with otherwise unknown parties that is essential to the mutual sharing of energy. Furthermore, the Dutch pilot also provides an example of the effect of co-dependency on mutual trust. As the parties have to limit their total consumption to stay within the contract with the DSO, they share a goal and are forced to collaborate.

In all pilots, we find a clear priority between the different scales at which sharing can take place. They prefer to keep the produced energy as local as possible, either for practical reasons such as alleviating local congestion (NL) or because of values of community (IT, PT). In practice, members envision a tiered approach where owners of production or storage assets get first access, followed by the community and, only if there is anything left, other parties such as nearby municipalities. In the case of the Italian and Portuguese pilot, these municipalities would be the final and largest tier, whereas the Belgian and Dutch pilot would even consider a wider scale.

5.1.2 Allocation method and pricing scheme

In the discussion with the pilot members about the allocation of energy, costs and profits, views converged into a universal principle around the allocation of surplus energy that would be both fair and effective. Weighing the various fairness principles with regards to distributional fairness, almost all members expressed how equality is of great importance to them but also saw the need for a proportional approach where additional effort is met with greater reward. This can be summarized in a principle of ‘equal opportunity’, where all members have a chance to receive available energy but miss out of if they do not make an effort to make use of it at the time that it is available (i.e., offer flexibility). It is important to note that, in these pilots, this concerns mostly surpluses of individually owned assets, and the owners of solar panels always have the first right to make use of the energy they produce.

When it comes to pricing, the members are less articulate but there is mention of a mid-market rate. In general, the members do not seek to make a business out of the sharing of energy but are interested in lowering energy bills. In the Portuguese pilot, a system that involves active bidding or price setting between individual parties is regarded as highly undesirable given the social tensions that are expected to be a result of this. Further input for pricing and the allocation of benefits is the concept of levelized costs, a pricing model that purely covers costs of production, in the case of individual assets this is mainly the devaluation of assets within a specified timeframe. Whilst this was only directly mentioned in the Dutch pilot, all pilots describe this importance of covering all investments and administrative costs before thinking about other principles for the distribution of potential profits. In the specific case of the Portuguese pilot, members share a unanimous opinion that producers of energy should not pay any additional administrative costs for sharing this energy with others. They require these costs to be paid for by the ones receiving the energy.

If a break-even point is surpassed, the pilots all have their own approach to the distribution of benefits. In Belgium, members lean more towards individual payout whilst the Italian pilot leans more towards communal investments. Across the pilots, various members mention the importance of allocating resources to cases of energy poverty. Following the example of Italy, it is advisable that each pilot discusses with its members how potential gains are distributed across individual payout, community investment (in energy and non-energy services) and the support of those who cannot make investments themselves, on a regular (yearly) basis.

5.1.3 Governance and decision-making

Many of the communities allow members to have direct influence through voting-system, with the exception of the Belgian pilot where the board of cooperation Klimaan makes day-to-day decisions to speed up this process. Instead of a direct vote, members are invited to provide input during gatherings, although it should be noted that many of the participants of this study are not (yet) a member. So far, the communities have had positive talks, but members of the Dutch pilot also point towards the fact that they have yet to make weighty decisions about big investments. Adding to that, Italian members stress the fact that the communities still exist of small groups of likeminded people, and that any expansions might complicate matters.

Across all pilots, the observation can be made that the presence of experts about legal and technical issues is highly beneficial to the quality of the discussions around important decisions. Expanding on their dependence on (outside) experts, most members support authorizing a leader or manager who makes day-to-day decisions on their behalf. It is paramount that this is someone that everybody trusts.

Given the small size of the communities, communication occurs during spontaneous encounters in public except for the organized meetings where votes take place. Generally speaking, members are happy with these existing structures. Members in the pilots foresee that they would like to join a meeting about the progress of the energy sharing activities a couple times a year, at moments where most are available to join.

5.2 Design of energy sharing platforms and tools

In this study we split the requirements across two sub-sections: core principles and design requirements for energy sharing. This division aligns with the structuring of the interviews as well as the various layers present in the technology (core architecture and front end). In this first sub-section of the synthesis, we cover the core principles. As introduced in the first touchpoint *setting up for energy sharing activities*, the requirements listed under this section describe agreements between the members of the communities that shape the very fundament of the activities they will undertake. These can be roughly delineated in the governance structure, sharing circles and allocation scheme. Together, the principles should encompass the parties that should/can be involved in energy sharing, their inter-relations, preferences for optimization algorithms and matters of procedural and distributional fairness (research questions 1, 2 and 3). Ideas about dealing with energy poverty are also discussed within the principles for fair distribution.

In this second sub-section, we outline the requirements derived from the study that are considered input for the design of energy sharing platforms and tools. Following the other touchpoints of *Interacting with energy sharing services* and tools and *billing and settlement*, these requirements dictate the general rules for the interactions that active consumers will have with any designed artifact (e.g., dashboards, games, (smart) meters, flexible assets, energy bills). As input for these design requirements we consider the values and motivations of active consumers, their current knowledge of energy sharing and their capability to participate in energy sharing or provide flexibility in general (research questions 1,3). Related to this, topics of energy literacy and recognitional fairness (research question 4) are also discussed. All design requirements are listed in Table 5.2 after which we provide additional context to the synthesis.

Table 5.2: Overview of requirements for the design of energy sharing platforms and tools

Requirement type	Pilot	Requirement description
Data sharing	All	Members are undecided at this time in the development, additional discussion is needed between members to arrive at a consensus on what data can be shared with whom.
Insight into consumption and production	All	Members desire insight into their own consumption on a 15-minute interval for each separate device. The same goes for production and storage information, for which members would also like to receive forecasts (ranging from the upcoming hours to the next 14 days).
	BE	In this specific case, members already benefit from basic rules of thumb and estimated data about device usage that help them be more efficient.

Requirement type	Pilot	Requirement description
Insights for flexibility	All	Members desire a change from *reactive* feedback (through energy bill) to *proactive* feedforward. Members would like customised tips for self-consumption or flexibility ahead of time.
Personalisation	All	Members' preferences for the following settings differ greatly and should be customizable: - Timing of recommendations and forecasts - Language (in Belgium: Flemish, English and Arabic) - Household specific assets - Personal and community-level insights (if data sharing rights are granted)
Embodied values	All	Members consider costs/profits and sustainability gains as core values. They would like see these values represented in the platform.
	PT, IT, NL	For these members, the percentage of (collective) self-consumption (self-sufficiency) is important too. They desire this to be visible in the platform.
Visualisation (recognition)	All	Members appreciate visual representations of data, yet these must be simple and intuitive, even to those still somewhat new to dashboards (using familiar visual representations).
Digitalisation	PT, BE, NL	Most members would like to make use of the platform and tool in a digital format only (apps, emails, websites). Only in some specific cases there is a desire for physical copies.
	IT	Additional research/prototyping with elderly members is needed to make sure the digital formats are accessible to them.
Automation	All	Members prefer automation of repetitive tasks in the interface and in daily routines as long as override options are provided.
Gamification	All	Members respond very differently to gamification concepts. For the few competitive individuals in the pilots, gamified elements in the interface can foster additional engagement.
	BE	Specifically for members in this pilot, extra caution should be placed on elements of competition. Members prefer to steer clear of monetary rewards that are influenced by gamified elements.

5.2.1 Active consumer values and motivations

All these collectives find a shared value in their ambition to be more sustainable and use energy responsibly. In addition to that, the prospect of saving on the energy bill is also universally appreciated, either because it lowers individual costs or gives the opportunity to invest in the communal infrastructure of services. This communal value is also a shared ambition across all pilots. For the Italian and Portuguese pilots, there is also value in being more self-sufficient, which expresses itself more so in their ability to influence the price of energy rather than its availability. This also holds true for the Dutch pilot, where the business context in which the members operate demands a higher level of price stability. Only for the harbour control on the Dutch pilot, self-sufficiency is important enough to invest in backup facilities.

The value of self-sufficiency seems to come from a larger sentiment of autonomy which is also reflected in the desire to control payments (Belgian pilot) and have more individual freedom. Another expression of autonomy is the desire for privacy. When it comes to sharing energy data, opinions differ quite strongly between members of the pilots, ranging between those who are ok with their data being almost public to ones that would rather not make consumption data available to the community.

5.2.2 Knowledge and information

During the talks with members of the various pilots it became clear that pre-existing knowledge of the energy system and energy sharing in particular varies greatly from person to person. A distinction can be seen among the pilot groups: Dutch pilot members are generally well-informed as a result of their collaboration with experts; Italian members possess only basic knowledge (with the exception of the Italian community manager); and Belgian and Portuguese participants remain entirely new to the concept. In some instances, these members also lacked the literacy to properly understand national energy system. With regards to their own use patterns, all pilots except the Dutch have no dashboarding yet and rely on yearly usage overview or bills to review their consumption behaviour and production figures. Therefore, they rely on assumptions and rules of thumb for making decisions on when to use energy.

In all pilots, there is a desire to get more timely information with a higher granularity. Across all the pilots, members indicated that they wish to receive information about their consumption on at least a 15-minute interval and per device. The same can be said for production and battery levels, which would preferably be forecasted some time ahead. With this information, members would like to adjust their own use patterns to suit sustainable production times. For some, it would also be desirable to get concrete recommendations for changing these use patterns. Whether all members would also like to provide access to all this data remains to be seen, however, as opinions about the extent to which data could be shared in the community differed per pilot member.

To meet the variety of preferences with regards to all information provided and its visual format, some personalisation options are necessary. Across the pilots, we see different preferences for the *timing* where forecasts and recommendations are provided to inform either momentary decision or long term planning, the types of *devices* that the system provides information about, the *language* in which the information is presented (specifically in multi-cultural communities such as the Belgian pilot) and how much information is shown about *others in the community/the larger system*. This last part is also highly dependent on the agreements that are made with regards to data sharing.

Finally, feedback about the values and motivations above largely concentrates around costs and sustainable energy use. These values need to be included to recognize the effort that members make. Additionally, we find that self-consumption is a community specific goal that should be reported on in the platform for the Italian, Portuguese and Dutch pilot.

5.2.3 Capacities and barriers for flexibility

As explained in the previous section, not all members currently possess adequate information to inform flexibility choices. They require insights that allow them to be more proactive instead of reactive. Whilst real-time information is desired, simple suggestions and rules of thumb about consumption and production patterns in the respective context can effectively inform daily routines (i.e., weather effects for production, 'quiet times' during the week with low consumption). Along with more timely and complete information, however, members need flexible assets to offer flexibility. With regards to assets, all pilots have their own barriers to overcome. In Portugal, there are a lot of electrical devices but use patterns are very similar across the members and largely determined by their work situation. In Belgium, use patterns differ quite extensively and participants are home relatively often as compared to members in other pilots, but they have only few flexible assets. On the other hand, members in the Dutch pilot have many flexible assets and their use patterns might be complimentary, but it is still unclear to what extent the members can actually change their behaviour, as this is largely determined by the weather and rush hours. Lastly, the Italian pilot seems most able to be flexible in the use of their assets, and this is reflected in the fact that they make a yearly profit through self-consumption. They can still improve by smarter use of EV charging infrastructure.

The use of such assets as well as the provision of information rely quite heavily on digital systems. Although quite some members of the pilots are not highly digitally literate, they do have prior experience with dashboarding apps in Portugal and the Netherlands, and in Belgium the members are always supported by younger relatives. Only in Italy some worries remain about the adoption of digital system by the elderly in their community. Other than that, almost all members acknowledge the benefits of digital system due their accessibility.

Lastly, more advanced systems such as automation or gamification could potentially support members in providing flexibility but have yet to become more concrete for all but one member who has already automated their beach pavilion in Scheveningen. For automation, members primarily need assets that support this but should also leave their devices turned on. In the Belgian pilot, a couple of participants continuously unplug their devices when not in use to save electricity. Gamification could be a nice addition for some members whilst others do not find it as engaging. At this point in time, none of the pilots seem to have a large enough share of these competitive members to enter in a game together. In the case of Belgium, worries also exist amongst the members that a game might be too frivolous considering the necessity of cost savings for the participants that need to be considered.

5.3 Value dilemmas and trade-offs

In the background section we highlighted some value dilemmas within the domain of energy systems. In the light of the findings presented in this chapter, we reflect on these dilemmas from the context of the pilot sites and introduce an additional dilemma.

5.3.1 Autonomy and control vs. convenience

For most members, autonomous systems have yet to prove themselves but the convenience they might bring is valued. From their current situation, they do not expect that their autonomy might be severely impacted as long as they have the ability to override. A potential example of good practice for setting up automation is provided by the Smappee service discussed in the Dutch pilot. Here, all devices and assets are shown in an overview together with buttons to turn them on or off, overriding the scheduled use patterns. This works well for the current user in the Dutch pilot even though they value autonomy greatly.

5.3.2 Transparency vs. privacy

As described in chapter 5.2, communities will still need to address the topic of privacy with their members and discuss what data will be shared with whom. This dilemma will be central to these discussions and will determine to what extent consumption and production data can be used to provide information to all members. From European Union (EU) regulations, it is imperative that all members agree to sharing their data individually, meaning that a vote on how data should be handled must enjoy unanimous support to avoid anyone dropping out.

5.3.3 Individual vs. communal and societal interests

The allocation principles discussed previously provide extensive detail about the position of pilot members in this dilemma. Across the pilots, there seems to be an emphasis on individual and communal interest, especially in Italy and Portugal. In the Netherlands, grid congestion issues of the DSO are also taken into account. For the remainder of the U2Demo project, it is interesting to observe whether individual and communal interest align with larger societal interest when optimising the local grid.

5.3.4 Confort vs. price and sustainability

Primarily supported by findings in the Dutch pilot, another dilemma emerges that opposes values of comfort with energy costs and sustainable ambitions. Especially in cases when the comfort of others (i.e., employees, customers) is affected, this is a difficult space to navigate. It might prove interesting to investigate how these trade-offs could be facilitated.

6 Conclusion and discussion

In this Chapter, we provide a reflection on the presented results and their robustness. We discuss both the studies weaknesses, as well as next steps in overcoming these shortcomings within the future work of the project.

6.1 Conclusions

Considering the large variations in pilot characteristics, our analysis of the pilot sites reveals a high degree of alignment regarding participants' interactions with energy sharing platforms. With regard to values in energy sharing, the primary motivations among all pilot members are to reduce their energy expenses and support sustainability objectives. Following the rhetoric of energy communities at large, the members in these communities express interest in reinvesting potential savings into communal infrastructure and reducing reliance on national pricing structures. In general, this democratic approach to the energy system is expected to bring about financial and social benefits for all members.

Capabilities of the members vary significantly, with limited energy literacy noted particularly within the Belgian and Portuguese pilots. For these households, communicating basic principles and rules of thumb that capture the effects of different times of day or types of weather could already prove effective in becoming more efficient. Nonetheless, all study participants value gaining advanced insights into their consumption and production patterns; when such information is delivered in an actionable format, it may empower them to provide flexibility during periods of grid congestion. A key change that needs to be made is swapping slow feedback systems (yearly insights) for timely feedforward systems (forecasts and hourly updates). However, the realization of this flexibility depends considerably on external circumstances and the composition of the community in terms of energy profiles.

Concerning the core principles and fairness of energy sharing, there is consensus across sites that all participants should have equal access to surplus energy once the asset owner's needs are met. There is also a preference for prioritising energy distribution within the originating community before sharing any remaining surplus with adjacent municipalities or further afield. In terms of procedural fairness, community members are generally content with only influencing important decisions while entrusting routine operational matters to a trusted leader or manager. This leader figure would need to be either knowledgeable on energy sharing systems themselves or get the support of experts. Together with a good understanding of the community, this would foster the trust needed for this leader to be granted this responsibility. Furthermore, the recognition of all individual values can be facilitated by visually representing pilot values through interfaces and dashboards. We find that these representations must be simple and somewhat familiar to the members to be interpreted correctly. Considering the lack of prior experiences in some pilots, this challenge might require additional attention.

6.2 Limitations

These conclusions to be analysed in the right perspective. They are derived from the findings of a study with 21 participants spread out across 4 pilot sites, each with a unique context. Although this diversity is also a strength, the number of participants per context is fairly small as a result. It is possible that the interviews did therefore not capture the full extent of information present in the members of the pilots. Also, to generalise the findings up to a point where they could inform possible standards and legislation, additional contexts should be incorporated in the synthesis.

Further limitations to the results originate from the capacities of the participants. As some of them had little to no prior knowledge about energy sharing of energy systems in general, they were unable to answer all questions fully. Especially in the case of Belgium, where participants were recruited in a suburb that is not yet fully informed about the community principles, additional input can be collected later in the project. The same can be said with regards to a lack of experience with platforms and tools, as this helps when envisioning new interactions. Once these members have more experiences in practice, it is likely that they change perspective and review their initial preferences. For these instances, it is important that additional research activities within the project follow up on this study with concrete prototyping activities that expand upon the experience that the members have with energy sharing systems. Furthermore, working with participants form various cultures had led to some difficulties with language barriers. Although we aimed to carry out almost all interviews in native languages, some interviews were executed with the help of a translator. This might have had a negative effect on the ability of participants to fully express themselves.

Additionally, members expressed various preferences that might conflict with each other once they are applied in sharing algorithms. To illustrate, principle of 'smallest circle first' might not be the most profitable or sustainable option in the end, whereas members do intend to fulfil these values. Once such trade-offs achieve this level of concretization, a shift towards renewed principles take place.

As a last limitation, we would like to stress the fact that this study has focused on the investigation of active consumer needs and important requirements from a social perspective. Whether all the requirements presented in Chapter 5 will be implemented remains to be seen as the energy sharing activities that will be developed must also adhere to legal and technical constraints. An overarching synthesis of all findings presented in the WP1 deliverables will shed more light on the actual concepts that are put forward and it is likely that trade-offs must be made between requirements of the respective domains.

6.3 Continuation of the work in U2Demo

As mentioned in Chapter 5 the current study still leaves some areas for further research. Now that an initial contact is made with the pilots and their members, we propose that regular meetings in the pilots are setup in line with the preferences for governance in the pilots. By organizing these meetings, the U2demo project could create the possibility to supply the pilots with additional expertise and conduct workshops for the deepening of the findings presented in this report. Concretely, an initial knowledge session would be organised in the Belgian pilot, followed by a series of workshops in all pilots aimed at creating a consensus on data sharing, pricing and the distribution of profits. Either simultaneously or after these workshops, technical partners might introduce prototypes of sharing platforms and tools to the members for the elaboration and verification of current design requirements. We propose that these prototypes are evaluated in a standardized manner through workshops and surveys. In line with the development goals of the U2demo project, this evaluation would include qualitative measurements similar to this study for monitoring progress towards energy literacy, usability and comfort in use, and quantitative measurements for engagement with the platform and the volume of energy shared.

Besides the development in the project itself, findings from this deliverable will also be discussed with related European projects to verify them and expand on their significance.

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APPENDIX A: Interview guide (EN)

Instructions for interviewer
[make sure to bring printed consent forms, participants information and a recording device. Prepare a notes document beforehand.]

Opening of the interview {5 min}

- Introducing yourself and other attendees
  [supplement with introduction elements such as thanks for participating, general introduction project]
- Review research
  [interview duration = 1 – 1.5 hours; space for questions about the information for participants; signs of the consent form].
- Any questions?

**Essential information*
With this research, we want to find out what your expectations and needs are for new energy services and technologies that can make it possible to better align the consumption and generation of energy with households and/or businesses in the area. This can have advantages because the energy supply can be arranged more sustainably, cheaply and fairly. We are curious what you find important if you were to adjust your consumption and/or generation to others and adjust your own behavior accordingly. Results of this research will be used to develop systems that will shape this alignment in this community. In addition, the findings are published as part of the European U2Demo study. Statements made during the investigation are only mentioned under a pseudonym in the report, but can still be recognized by acquaintances.

Respondent introduction {10 min}

- Tell a short intro about yourself
- When did you come to live/work here?
  - Ask questions about experiences
- Why did you come to live/work here?
  - To what extent did the energy community play a role?
  - To what extent did the sustainability of the home and energy supply play a role?
- Can you describe what your contact with other people in the neighborhood looks like?
  - *(ask questions: fleeting contact with neighbours, close relationships/friends/family, whether they are active in neighbourhood initiatives or organisations)*

I - Knowledge of energy sharing

1. **Energy sharing and relationships with *peers* {15min}**

**Short description of the concept of energy sharing: Joint supply of energy within the community in which mutual agreements about price and supply of energy determine who gets what for what price. This can achieve various goals such as sustainability, cost reduction and an increase in control of the energy supply. At the same time, energy sharing systems require varying degrees of involvement and the provision of data about personal usage.*

In [description of pilot], *energy is shared / energy will be shared. We would like to hear what you think about energy sharing and what you think is important.*

- What do you know about the ambition to start sharing energy? / What do you know about how energy is shared within the community?
- What do you think of sharing energy?
  [*specifically ask about 'energy sharing as it is currently set up' in pilots where sharing is already taking place, otherwise ask about what they generally think of the concept*]
- Why do you want to participate in energy sharing? Or why not?
  1. What are the main reasons for you? Asking further questions about the values that are mentioned:
     1. Sustainability
     2. Financial benefit
     3. Using your own electricity as much as possible (self-sufficiency)
     4. Altruistic / social motive
     5. Convenience and comfort
  2. [Possibly ask further questions using examples]: *In order to make optimal use of the electricity generated within the community, members of the community can adjust their energy consumption to each other and to the electricity generated. This can ensure that everyone has more financial benefits, or that the most CO2 savings are achieved. It is also possible to steer towards using the own generated electricity as much as possible.*

- What are the disadvantages of sharing energy for you? / What disadvantages do you expect?
- Do you know other people who are / likely to participate in energy sharing – in this community? Can you describe the contact you have with these people?
  - Can you name different circles of contacts? (*e.g. neighbors, family, companies in the area, people or organizations not known to you)*

2. **Knowledge of energy consumption, energy costs and energy production {10 min}**

- How much money do you currently pay monthly/annually for energy?
  - How do you feel about this?
- What do you know about your energy usage profile?
  - When during the day do you (your household) use the most energy?
  - And when is it the least?
  - How does this differ over the seasons?
- Do you generate energy with solar panels?

  - Do you aim to consume that energy yourself? If so, how?
  - Can you use all that energy yourself?
- What do you know about the others in the community?
  - About their energy consumption
  - About their energy bills
  - About their devices or intended investments/purchases?

II - Energy sharing scenarios
It's possible to share energy in different ways and with different people. We now discuss the circle of people with whom energy is likely to be shared in this pilot.

1. Share with family and friends in the community {10 min}
- Would you like to give or receive energy within this circle of people?
  - Would you adjust your consumption if someone else made energy available or asked for it?
- What would you like to agree on a fee/payment for that shared energy? [*possibly ask questions: money, vouchers, energy at another time, CO_2 savings...*]
- What would you like to do with the (financial) benefits of energy sharing? Think of paying this out among the members or investing in the community.
  - [*Ask questions about distributing among participants*] How would you like to divide it among the participants? [*Discuss the specific scenario that will apply to this pilot*, or *consider both individual and collective generation*].
  - [*Ask further questions on 'spending on things in the community'*]. What kind of things do you think about?
- What would you consider fair when it comes to distributing the energy?
  - [Use as an example the fairness principles: driven by impact, solidarity and capacity, individual rights and freedom and distribution based on contribution]

2. Sharing with nearby districts or municipalities {10 min}
- Would you like to give or receive energy within this circle of people?
  - Would you adjust your consumption if someone else made energy available or asked for it?
- What would you like to agree on a fee/payment for that shared energy? [*possibly ask questions: money, vouchers, energy at another time, CO_2 savings...*]
- What would you like to do with the (financial) benefits of energy sharing? Think of paying this out among the members or investing in the community.
  - [*Ask further questions about distributing among participants*] How would you like to divide it among the participants? [*Discuss the specific scenario that will apply to this pilot*, or *consider both individual and collective generation*].
  - [*Ask further questions on 'spending on things in the community'*]. What kind of things do you think about?
- What would you consider fair when it comes to distributing the energy?
  - [Use as an example the fairness principles: driven by impact, solidarity and capacity, individual rights and freedom and distribution based on contribution]

3. Sharing with the national grid {10 min}
- Would you like to give or receive energy within this circle of people?

    - Would you adjust your consumption if someone else made energy available or asked for it?
- What would you like to agree on a fee/payment for that shared energy? [*possibly ask questions: money, vouchers, energy at another time, CO_2 savings...*]
- What would you like to do with the (financial) benefits of energy sharing? Think of paying this out among the members or investing in the community.
    - [*Ask further questions about distributing among participants*] How would you like to divide it among the participants? [*Discuss the specific scenario that will apply to this pilot*, or *consider both individual and collective generation*].
    - [*Ask further questions on 'spending on things in the community'*]. What kind of things do you think about?
- What would you consider fair when it comes to distributing the energy?
    - [Use as an example the fairness principles: driven by impact, solidarity and capacity, individual rights and freedom and distribution based on contribution]

As you can see, the scenarios are always about sharing energy with different circles of people – from known to unknown.

- Which 'circle' do you prefer to share energy with? Why?

III - Interaction with systems / software

To make energy sharing possible, information about energy production and energy consumption must be shared between households/businesses and other parties such as the energy supplier, network operator, etc. Depending on how energy sharing is arranged, it is also necessary to receive information in the household / company that you can do something with at that moment. Think, for example, of an app in which you indicate whether you are at home today, or whether you plan to charge an electric car today. This type of information makes it possible to optimally use energy sharing for community goals – such as financial benefit, sustainability or social goals.

Overview of phases in the energy sharing process

1. **Touchpoint agreements about energy sharing {10 min}**
    - How are agreements currently made about how energy is shared?
        - How much say do you have in this?
        - How do you experience this way of making decisions?
    - How would agreements on energy sharing ideally be made?
        - How often should this be discussed? [Discuss multiple frequencies]
        - Is that the same if energy sharing has been going on for a while?
    - Do you prefer to make this choice individually or in consultation with others?
        - How would you prefer to pass on your preferences? *(a conversation, a questionnaire, this interview, via a platform, something else*)
2. **Touchpoint usage phase (price signals, trading and feedback) {15 min}**
    - Are you currently using apps or dashboards on your phone or in your home with information about your energy consumption and/or production?
        - How do you use them?
        - How comfortable do you feel using them?
            - How do you further assess your digital skills?
        - What do you think of that app/dashboard/...? [ask questions, what do people like, what don't they like]
        - What is still missing?
    - How do other people in your household feel about this?

- What do you want to see and do on an energy sharing platform?
    - [Ask questions: how much shared energy; revenue; percentage of own energy consumed; how much does it consume compared to neighbors. Etc.]
- Would you like to receive tips for energy saving?
- To what extent would you like to exercise control over the energy that is shared by performing actions yourself?
  [examples to illustrate: think for example of approving a transaction in an app to share energy with a specific neighbor, or 'bidding' on available energy]
    - At what times is this control important?
    - How would you like it if you were asked for input [daily, weekly, or monthly] about your (expected) energy consumption.
    - What can be automated?
    - How does this differ over time, when energy sharing has been going on for some time?

3. Touchpoint settlement {15 min}

- What does the current settlement of the energy bill look like?
    - Which information is most important to you?
    - What more do you want from this settlement?
- What expectations do you have of a settlement in the case of energy sharing?
    - How does this differ from a 'traditional' energy bill?
- To what extent can your consumption and generation data be reflected in this bill?
    - To whom may this information be available?
    - Does this also apply during the other phases of the energy sharing process? [Think, for example, of a dashboard of the community, which shows the consumption of the group as a whole, or also information about consumption of individual members]

I ANNEX I

Initial identification of collective energy activities in the U2DEMO pilots

This annex provides an initial overview of activities undertaken by energy collectives within the U2DEMO project. A set of activities was compiled through interviews with pilot leaders conducted approximately 2–3 months after the project's launch and presented in a form that can be used as a basis for consumer-inclusive IT development. This overview serves as a first step toward the development of IT solutions that actively involve and support consumers. The set is used as a starting point for the work in U2DEMO Task 1.2 (Consumer Engagement) and Task 2.1 (Functional Architecture).

In this Annex we will use the term **energy collectives** a as a neutral description of a variety of forms in which active customers can act in as a more or less organized group including both legal entities and active consumers just working together.

I.1 Background

This development of the set of activities builds upon research conducted in 2021-2023 on the activities of energy collectives in the Netherlands.[6] That research identified, by studying the activities of existing Dutch collectives[7], several activities of energy collectives in and around electricity markets including those in pilots. The study also highlighted activities that collectives aim to engage in moving forward, but which are currently constrained by legislation and regulatory frameworks.

Aim of the study was to provide insight into how groups of connected customers can be empowered to develop energy activities now and, in the future, and to showcase that groups of connected customers can engage in various activities.

Based on the Dutch collectives study, two main categories were identified (*market and non-market activities*) with in total seven sub-categories of activities (see figure below)

[6] Winters, E & Van der Veen, A, Energiegemeenschappen in veranderend juridisch landschap, TNO 2023 R10525

[7] Activities of energy communities in Loppersum (Lopec), Heeten (Endona, GridFlex project), Loenen (DE-central project), Amsterdam Buiksloterham (Schoonschip) and Houten (Ecowijk) were studied.

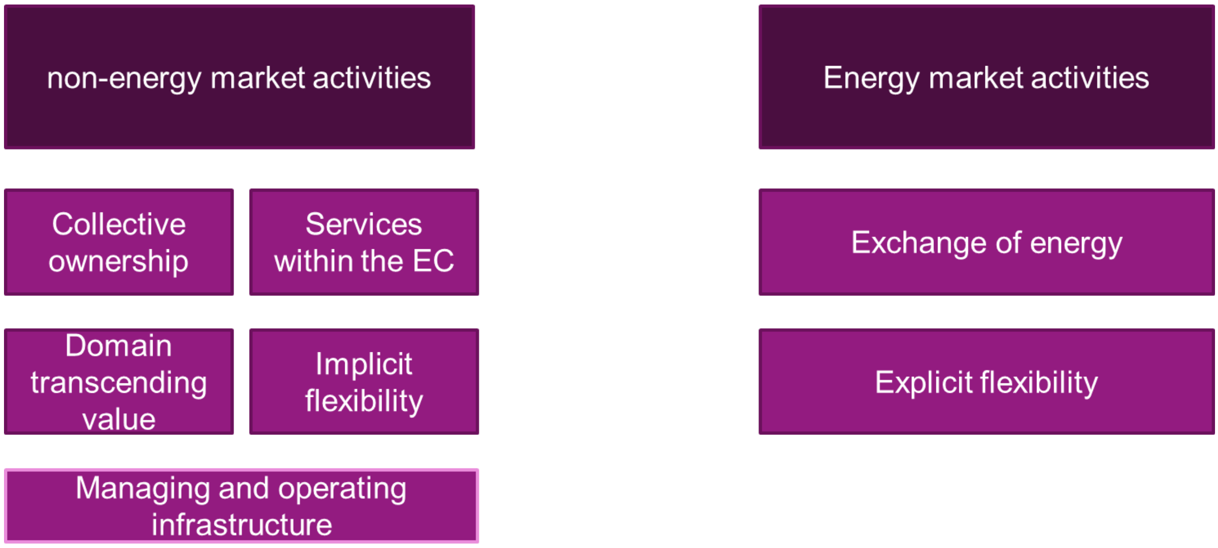

Figure I.1 – Categories of activities as identified in the 2023 study on Dutch energy collectives[6].

Non-energy market activities are defined as actions that, while oriented toward energy objectives, do not involve direct participation in an organized energy market. These activities may support energy system goals (e.g., demand reduction or efficiency improvements), but they do not entail the exchange of goods or services as or through a *market participant*.
In contrast, energy market activities involve the explicit offering of energy-related products or services on formal markets i.e. wholesale, balancing and congestion service markets.

Besides identifying the activities, a legal analysis was carried out to determine the legal classification of each activity, whether a collective is permitted to undertake it, and under which conditions. A key finding of this study is that the legal definition of an activity often allows for flexibility in its practical implementation. For instance, an activity may be classified as peer-to-peer trading in legal terms, while in practice it merely involves administrative settlement, without any real exchange of electricity.

This insight led to the follow-up question on how different countries deal with this legal 'flexibility'. The differences in implementation were further examined in a study on 'multi-supplier models' commissioned by Directorate-General for Energy.[8] This study explored how EU member states are implementing energy sharing. It found that various models are possible: some enable the actual exchange of energy, while other models rely on price signals to encourage collective self-consumption.[9]

In Figure I.2 we name and summarize the energy sharing registration models identified in this study.

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[8] European Commission: Directorate-General for Energy, Fraunhofer Institute for Systems and Innovation Research ISI, Guidehouse, McKinsey & Company, TNO, Trinomics, Utrecht University, Veen, A. v. d., Winters, E., Fumagalli, E., Klobasa, M., Breitschopf, B.Seigeot, V., *Multi-supplier models and decentralized energy systems – Energy sharing approaches*, Publications Office of the European Union, 2023, **https://data.europa.eu/doi/10.2833/730792**

Behind the meter model:

Sup-supply model:

Adjustment of the bill-model:

Cash back-model:

Sharing is registered as part of	Balance responsibility	Collection of grid charges and taxes
Metering process	Yes, the energy sharing leads to a change in volumes that fall under a certain Energy Supplier and so a certain BRP.	If a reduction on grid charges or taxes applies for energy sharing, the Energy Supplier has to take this into account when he invoices his customers involved in sharing arrangements.
Allocation process	Idem.	Idem.
Supply settlement process	No, volumes on the perimeter of the BRP do not change under influence of energy sharing.	Idem. Furthermore, the Energy Supplier might change his procedure to calculate the volumes that apply to grid charges and taxes, since he should also take into account the energy sharing: he cannot take the values registered at the Accounting Points.
Dedicated settlement process	No impact.	No impact. If a reduction of grid charges or taxes applies, this is taken care of in the dedicated settlement process.

Source: Veen, A., Winters, E., Fumagalli, E., Klobasa, M. et al., *Multi-supplier models and decentralized energy systems – Energy sharing approaches*, Publications Office of the European Union, 2023, p. 28

Figure I.2 – Energy sharing registration models. The names on the left are not introduced in the original study.

These two studies lead to the following conclusions:
1. Legal definitions only offer limited insight into how activities are shaped in practice, and
2. The design and implementation of activities like energy sharing and peer-to-peer trading vary significantly between member states.

I.2 Method

The initial list of observed activities derived from the Dutch collectives in 2021 and the energy sharing administration models identified in the 'multi-suppliers model' study[8] were used as a starting point for identifying the activities of the U2DEMO pilots in a form relevant for the development of IT. Each pilot was interviewed[10] and asked to assess, for each activity, whether they were currently engaged in it, or interested in developing it in the future.

We are aware that the starting point - the long list of activities derived from the previous studies, influenced the way the activities are described. Such starting point was necessary in the project (asking the open question 'what activities are you planning to do?' would have resulted in answers with different levels of depth and focus) but had as drawback that it required energy collectives and professionals from different backgrounds to reason about activities in terms they are not familiar with. In the interviews and desk words experts familiar with the framework were involved to improve the quality of the responses.

Subsequently, in close collaboration with each pilot, a tailored short list was compiled, identifying the specific activities they were actively pursuing. Based on this comparative analysis, the comprehensive list of activities was refined into a set of 12 core activities that are most relevant across the pilots; 1. *Joint-self sub supply, 2. joint self-supply, 3. collective KW-max balancing, 4. collective self-consumption, 5. collective flexibility activation delivery to a flexibility service provider, 6. optimization for local sustainability goals, 7. energy monitoring*

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[10] Link to the interviews: Notes_Deepening introduction IT pilot_271124_(english).docx, Notes_Deepening Introduction PT pilot_200125_(english).docx , Notes_Deepening introduction NL pilot_191124_(English).docx, Notes_Deepening introduction BE pilot 251124 (English).docx

and advice services, 8. energy community as an Esco, 9. collective controlling rights, 10. collective community investments, 11. secondary billing and 12. collective self-balancing.

This selection includes both activities that are currently being implemented and those that pilots aspire to develop in the future and for which dedicated IT tools and support will be necessary. The activities cover both energy market and non-energy market activities and fall into multiple activities. Also new activities were identified that were not on the initial long list.

The list of activities was further evaluated by examining activities from the perspective of IT development: What distinguishes one activity from another, and to what extent are these differences relevant for IT development and discussing choices in IT within an energy collective?

I.3 Results

The activity identification and evaluation process led to a set of activities of energy collectives in scope of U2DEMO presented in a form that supports IT development. This set of activities is presented below along the 9 categories shown in Figure I.3. 7 of these categories were introduced in the background study (Figure I.1). These 7 categories were not specifically defined to distinguish activities based on the type of information exchange. They were further refined using insights from evaluating the activities of the U2DEMO pilots. We also identified the need to add 2 new categories. All 9 categories will be introduced and the activities of the U2DEMO pilots will be discussed per category. We motivate the introduction of new categories and describe the deviations from the initial 7 categories.

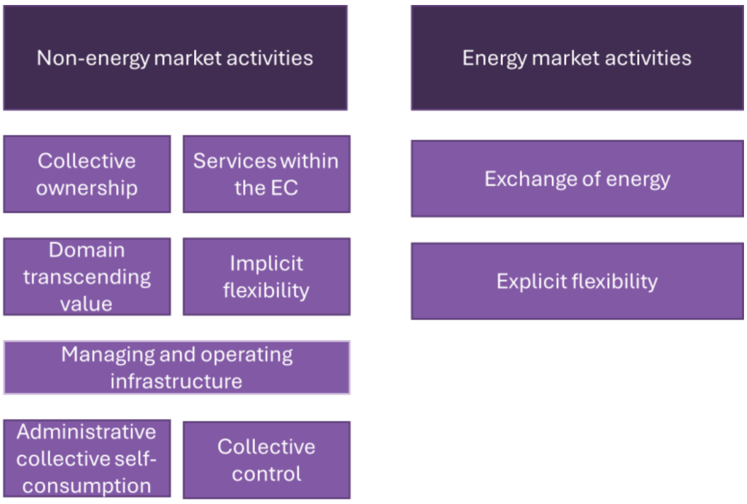


Figure I.3 – Categories of activities. This is an updated version of the figure presented previously in Figure I.1.

I.4 Energy exchange

The category **Energy Exchange** encompasses activities in which members of an energy collective transact energy among themselves or collectively bring energy to the market. The activities in this category are ‘energy market activities’.

In the activity long list, three types of energy exchange activities were defined. Joint selling of energy to an energy market participant, and two forms of supply to community members. In the first form, the energy collective acts as the main supplier of the members of the community.

In the second form ('sub supply'), the energy collective supplies energy to its members as a secondary supplier.

I.4.1 Key characteristics

Energy exchange activities are characterized by the requirement for interfaces between the retail market and wholesale market domain. This is needed to ensure parties with responsibilities in these domains such as energy suppliers and balance responsible parties take the activity into account in their processes and functioning of the electricity market is guaranteed.

Energy exchange activities are called 'energy supply' , 'energy trading' or 'energy sharing' but these words in a social, business or regulatory context do not give a final answer on whether or not the type of information flows associated with energy exchange should be implemented. To determine whether there is an 'exchange of energy' we look at two aspects:

- the exchange requires a transaction in the domain of wholesale and/or balancing markets, and as such requires agreements about balance responsibility[11]
- the exchange is about energy rather than flexibility

Energy exchange activities have similarities with explicit flexibility activities as they are both energy market activities. They both require interfaces between the retail and wholesale market domain but the timing, order and counterparts of information exchange is different.

I.4.2 Mapping of the U2DEMO pilots

Joint selling was not found as an activity in scope of the U2DEMO pilots and so not added to the short list. Furthermore, we identified that only in the NL pilot energy exchange is a relevant category. In the BE, PT and IT pilot energy sharing takes place via models that do not require an agreement with a balance responsible party about the exchange of energy. This results in different needs in terms of information interfaces, see the activity 'collective self-consumption registration'.

The situation in the NL pilot is a unique situation (not typical for energy communities in Netherlands) where the community interacts with the electricity system via one connection point. At this connection point, a single energy supplier is active who treats the community as a one large customer and as such can offer services that are not typically offered or cannot be offered to energy collectives in other situations.

In the interview, the NL pilot leaders explained their intention to share energy within the community but explained that barriers for this activity can be found in the lack of good tariff structures, incentivization and transparency. With energy sharing they mean the attribution of a certain amount of energy produced in the community to a certain member. In the NL pilot this can be done within the community as a settlement-only process without interaction with the energy supplier, however the wish was identified to model this 'energy sharing' as 'joint self sub-supply': as if the members of the energy community have their own energy supplier.

[11] The agreement about balance responsibility can be foreseen via different balance responsibility models. For more information see: Implementing the CEP: Options for Balance Responsibility for Active Consumers in the Netherlands | IEEE Conference Publication | IEEE Xplore

In this way the NL pilot can be used to demonstrate energy sharing in the form discussed currently in the Netherlands (see report T1.1).

Joint self-supply has been identified as future option for the collective in case the dependence on the energy supplier results in barriers to take part in or benefit from activities. Due to the complexity of implementation this is not the preferred option at the moment but reflecting on this option after the demonstration phase was identified as useful.

Table I.1: Energy exchange activities relevant to the U2DEMO pilots

Activity	Description	Key information exchanges	Pilot
Joint self-supply	A collective supplies electricity to the members of the group as a single entity. None of the members has another primary energy supplier.	The collective acts as energy supplier and as such needs to implement all information exchanges that are required for energy suppliers. Regulation might lead to special requirements (exempted or additional tasks for certain legal forms of collectives acting as energy supplier).	NL - future
Joint self sub-supply *(energy sharing via sub-supply model)*	The community members have a primary supplier but are also supplied from the community. The sub-supply is registered as allocation which means that actual energy is delivered between the members of the community.	The collective should communicate the amount of energy to sub-supply to a party that can communicate the sub-supply to the energy supplier and BRP such that they can take that into account in the energy trading and balancing strategy. Furthermore, often (such as in the NL pilot) an internal billing process might be needed and/or a shared energy notification process. The latter is needed such that flexible assets can respond to the energy sharing incentive.	NL

I.5 Collective self-consumption registration

In the initial list of activities collective self-consumption that does not fall in the category ‘energy exchange’ was presented as ‘implicit collective self-consumption’ and categorized under ‘implicit flexibility’. This initial description of the activity does not include the full set of information flows between collectives, their members and the outside: it considers only the action of activation of flexibility in the ‘operation’ phase: only the response with flexibility to the incentive. As the IT development at energy collectives include also the registration, we added a new category ‘Collective self-consumption registration’.
Presenting the act of responding to an incentive to optimize collective self-consumption as a single activity makes barely sense as we expect there is always an interaction with a certain ‘energy sharing registration model’.

I.6 Key characteristics

Given the definition of energy exchange above, we classify activities that register a certain transaction (they register ‘shared’ or ‘jointly consumed’ energy) but the registration doesn’t require an interaction with the wholesale and balancing market as ‘collective self-consumption registration’.

This type of activity is characterised by a registration of an amount of energy shared that results in a benefit for the members. This benefit can come via the energy bill (energy sharing via the adjusted energy bill model) or via the a separate cash-back or voucher provision process.

The administration of energy sharing results in an incentive to optimize collective self-consumption. If the community responses to this incentive it might be beneficial, as for all implicit flexibility activities (see below) to notify the energy supplier about this activation: flexibility activation that is not taken account by the energy supplier/ BRP can increase the costs of trading and balancing.

I.7 Mapping of the pilots

In scope of the PT, BE and IT pilots is energy sharing in a form that does not result in an energy exchange. In PT and BE energy sharing has an effect on the energy bill. The collective has to communicate about the sharing with the DSO. In Italy, energy sharing information is shared with Gestore dei Servizi Energetici to receive a cash-back.

In the PT demo the idea was discussed to use dynamic sharing coefficients[12]. In the current energy sharing mechanism in Portugal only static coefficients are possible. Testing the dynamic sharing coefficients would be possible by given another (virtual) benefit, e.g. in the form of vouchers.

Table I.2: Collective self-consumption activities relevant to the U2DEMO pilots

Activity	Description	Key information exchanges	Pilot
Energy sharing via adjusted energy bill model	A collective facilitates the sharing of energy from jointly or individual owned assets to individual members. This means the collective communicates the energy sharing to a certain party that results in an adjustment on the energy bill.	The collective communicates the amount of energy to be shared, the sharing keys and/or sharing methodology preferences to a party that facilitates the sharing process resulting in an adjustment of the energy bill. The adjustment on the energy bill has implications for the energy supplier as such it might be beneficial to notify (once or daily/hourly) the energy supplier about the sharing. It might also be needed to settle between the members of the community. Furthermore, the sharing results in an incentive to optimize the amount of collective self-consumption using energy flexibility. To plan and activate this flexibility communication to the members and their assets information exchange required.	BE, PT
Energy sharing via cash-back model or vouchers	A collective facilitates the sharing of energy from jointly or individual owned assets to individual members. This means the collective communicates the energy sharing to a	This model is similar to the model above with the difference that there is no need to communicate the sharing with the energy supplier.	IT PT- option to use vouchers

[12] https://www.cell.com/heliyon/fulltext/S2405-8440(23)07807-6

	certain party that results in a cash-back separate from the billing of energy.		

I.8 Explicit Flexibility

The category Explicit Flexibility refers to the deployment of collective flexibility:

1. on electricity markets or
2. directly to a system operator e.g. for balancing or congestion management or
3. to a third-party market participant aiming to improve its position on the market.

In the USEF Flexibility Value chain[13], these activities are categorised in four type of offerings each indicating the type of value the flexibility adds to the electricity system: constraint management services to grid operators, adequacy services to a party with an obligation to ensure security of supply, wholesale market optimization to market participants or balancing services to the transmission system operator.

A community can take the role of a flexibility aggregator itself by bundling flexibility and selling it to parties that require it, or it may utilize the services of a flexibility aggregator. The provision of explicit flexibility services is considered an energy market activity. As illustrated in the USEF Flexibility Value chain in Figure I.4, an aggregator has different roles when offering these services and as such needs a different license.

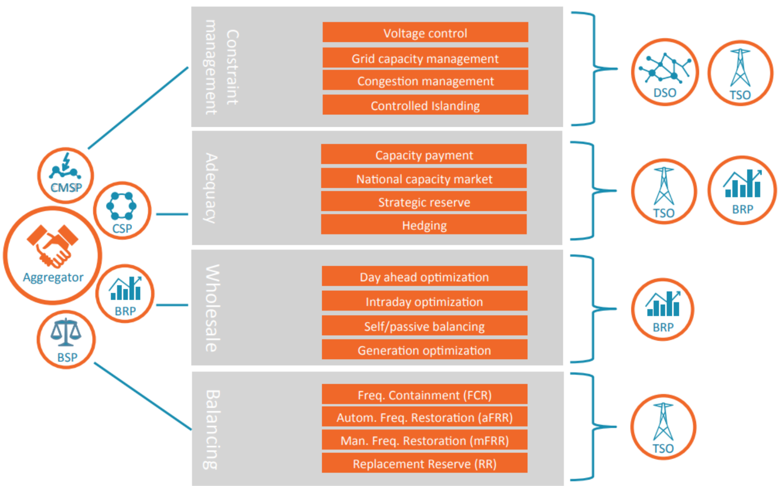


Figure I.4 – USEF Flexibility Value Chain[13]

I.8.1 Key Characteristics

Explicit flexibility is an energy market activity. It requires, like energy exchange, a transaction in the domain of wholesale and/or balancing markets, and as such requires interfaces

[13] USEF: The Framework Explained, Hans de Heer Marten van der Laan Aurora Sáez Armenteros, May 2021, available at: https://www.usef.energy/app/uploads/2021/05/USEF-The-Framework-Explained-update-2021.pdf

between the retail market and wholesale market domain. The information exchanges for explicit energy flexibility were identified by USEF[14].

USEF does not include the role of an energy collective in providing flexibility. In principle, the energy community can adopt either the role of aggregator or the role of the active consumer, but in practice the EC functions between these two roles. Information exchanges for explicit energy flexibility as defined in USEF needs to be linked to processes in the energy collective such that both on the level of the EC as a whole as on the level of individual members the flexibility activation is optimized and aligned with other stakeholders such as the energy supplier.

I.8.2 Mapping of the pilots

Explicit flexibility is identified as a future activity for the pilot in Italy but given the state of the pilot it was not possible to further identify and evaluate this activity. In the NL pilot explicit multiple flexibility activities take place already.

The first activity is collective self-balancing. This activity was initially not identified as a separate activity as it was seen as part of the process of energy supply via the supplier SEP. When we took a closer look at this activity we identified that the community offers a self-balancing service to the supplier and so BRP, an explicit flexibility product type but not worked out in detail in USEF. Unique aspect is that the collective balances over the profiles of all their members, this requires additional information exchanges between the members of the EC.

The second activity is collective flexibility activation to a Flexibility Service Provider (FSP). In the Dutch pilot the delivery of flexibility for day-ahead congestion management has started. The collective communicates to an independent aggregator licensed as Congestion Service Provider about the flexibility to offer on the flexibility platform GOPACS. When the flexibility offer is accepted, this activation is taken into account the schedule send to the energy supplier in the process ‘collective self-balancing’. In this way no additional Transfer of Energy is needed between the independent aggregator and the energy supplier.

Table I.3: Explicit flexibility activities relevant to the U2DEMO pilots

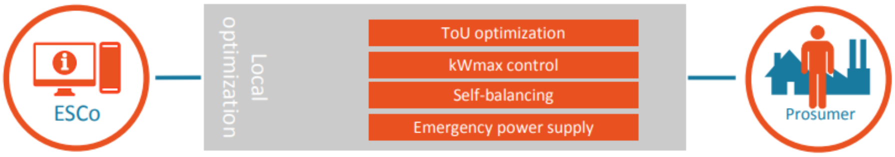
Activity	Description	Key information exchanges	Pilot
Collective self-balancing	The collective is a as a 'balancing group' within a larger portfolio of a BRP. The collective activates flexibility to balance the portfolio: balancing supply and demand and trade.	Sending schedules to the energy supplier/BRP. The schedules become a target profile the collective has to follow. Deviations from the target profile are settled against imbalance costs. Members have to be involved in the process of scheduling and responding with flexibility to the target profile.	NL
Collective flex activation delivery to a flexibility service provider	The collective offers flexibility activation to an aggregator as a whole instead of contracting an aggregator on an individual basis. A certain amount of flexibility is sold by the collective to the aggregator.	For the interaction between the aggregator in the role as FSP and energy supplier/BRP USEF can be used. The interaction between the energy collective manager communicating with the aggregator (acting as a flexibility service provider) and the members of the community adds additional information	NL

[14] See Section 4.2 of USEF: The Framework explained.

		exchange needs such as scheduling, activating flexibility and settlement on the level of individual members and optionally their energy suppliers/BRPs.	

I.9 Implicit Flexibility

The category 'Implicit Flexibility' refers to the use of collective and individual flexibility to achieve shared benefits behind the meter or within the collective domain. This could include, for example, cost savings under dynamic pricing schemes or consuming as sustainably or locally as possible. In this case, flexibility is directly used for the benefit of the collective, as opposed to trading a flexibility product with a Flexibility Requesting Party (see Explicit Flexibility).



I.9.1 Key characteristics

The use of implicit flexibility is not an energy market activity; the flexibility is not traded on a market and is not visible on the level of wholesale and balancing markets. Therefore key information exchanges including the monitoring and control of flexibility targets and information exchanges to parties outside the collective is not required.

However, the energy supplier still want to incorporate these activities as accurately as possible into their forecasts for energy trading and balancing purposes. He may impose additional requirements or costs in response when he is not capable of doing this well enough.

I.10 Mapping of the pilots

In the NL pilot two implicit incentives for flexibility activation were identified. The balancing of the community to meet the kWmax constraint defined on the joint grid connection level and the preference of community members to contribute jointly to local sustainability goals. The latter is prioritized lower than the first.

In the BE pilot kWmax balancing was identified as there is a limit for the community on using the network. Taking this constraint actively into account requires investment in the monitoring and control flexibility.

Table I.4: Implicit flexibility activities relevant to the U2DEMO pilots

Activity	Description	Key information exchanges	Pilots
kWmax balancing	An energy supplier or grid operator incentives the collective to take care of a kWmax constraint. This may be a fixed constraint or a constraint that is planned e.g. day-ahead.	The collective needs to implement a monitoring system and a coordination approach that together ensure the kWmax on the group level is ensured. This requires communication within the collective. Communication to external stakeholders is not necessary but can be beneficial to reduce energy sourcing and balancing costs of the supplier.	NL, BE
Optimization for local sustainability goals	The collective activates flexibility to meet local sustainability goals, e.g. they store solar energy produced in the community to use at a later moment. Often this goal is combined with other incentives. Add this only if the collective activates certain flexibility for this goal and not other goals.	The collective needs monitoring of the local sustainability goals and a coordination approach that help the collective to optimize towards this target.	NL

I.11 Community services

The category ‘Services within the community’ includes all services that a collective provides to its members, either for a shared or individual purpose within the community. These services are often characterized by the fact that they are cheaper, easier, or only feasible to organize as a community.

Community services on the activity long list included (green) energy monitoring and advice services, collective purchase of energy products, contracts and services for individual use and supporting members as an Energy Service Company (Esco).

In the IT, BE and NL pilots there monitoring and advice services are in place or planned for. These monitoring and advice services are scoped as ‘long term insights’ that don’t have effects that need to be taken into account in daily processes.

In all four pilots the activity Energy Collective as an Energy Service Company was identified as relevant activity, but we also identified that the description of this activity did not well cover the information exchange needs. Therefore, we decided to introduce a new category ‘collective control’.

I.12 Collective control

The collective needs a way to incentive members to respond with their flexibility to implicit or explicit flexibility goals including the optimization of collective self-consumption. There are different way to do this as shown in the Energy Management Matrix in Figure I.5.

The matrix classifies approaches into four main categories, with the vertical axis distinguishing if an approach makes decisions on local issues locally or centrally, while the horizontal axis plots whether an approach uses one-way or two-way communications. Figure I.5 shows this matrix with four general classes of energy management approaches filled in: top-down switching, price reaction, centralized optimization, and transactive control and coordination.

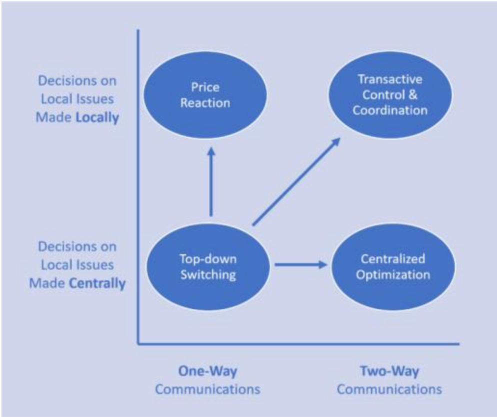


Figure I.5 – Energy Management Matrix (Kok, 2016)[15]

Collective community investments or agreements within the community result in collective controlling rights which means the collective has *as a group* a say in how to control energy assets providing renewable energy or flexibility. The governance for this collective controlling rights should be implemented in the community governance and should be integrated in the operational processes of the activities that include the participation of these assets. This means that the community should agree on where decisions are made and how the communication about decisions takes place.

In ICT systems assets ownership information should ideally not be assumed implicitly as it restricts the applicability in energy collectives with different other ownership and governance structures. By introducing the activity of 'collective control of individually or jointly owned assets' as a separate activity it is possible to bring the ownership dimension in all kind of activities.

Table I.5: Collective control activities relevant to the U2DEMO pilots

Activity	Description	Key information exchanges	Pilots
Collective control of individually or jointly owned assets	The collective has together a say about how to control assets. These rules are defined in community agreements and should be implemented in other activities where control of assets takes place.	The community agreements about control – where it takes place and how (see energy management matrix) - should be implemented in digital control systems. It might be beneficial to implement these kind of agreements as separate processes instead of rules implemented within activities. This needs to be further explored.	NL, BE, PT, IT

[15] K. Kok and S. Widergren, "A society of devices: Integrating intelligent distributed resources with transactive energy," IEEE Power and Energy Magazine, vol. 14, no. 3, pp. 34–45, 2016.

I.13 Management and operation of infrastructure

The category management and operation of infrastructure includes activities in which the energy collective acts as the operator (because of ownership or other arrangement) of distribution infrastructure that connects its members to one another and to the broader energy system. This may involve infrastructure for heating, (renewable) gas pipelines, or electricity cables.

In scope of the U2DEMO pilot in the Netherlands is the management of a local electricity grid by an energy collective. The control of flexibility to ensure grid constraints is expected to be part of implicit and explicit flexibility activities introduced earlier. On top of that, in the Dutch pilot the monitoring e.g. for maintenance needs of the local grid is a task of the community.

According to the project plan such tools will not be developed but we need to ensure that the software supporting energy flexibility activities are aligned with grid monitoring processes such that flexibility actions are executed within grid safety limits.

I.14 Collective ownership

The category Collective Ownership includes procurement activities in jointly owned energy sources (such as solar panels, wind turbines, heating installations) and purchases of shared resources and services (such as distribution grids and energy management systems or services). Support for individual purchases—i.e., 'collective purchasing of individual goods and services'—falls under the category 'services within the community'.

Carrying out activities (e.g. selling the energy produced together to the market) with these jointly owned assets is considered a separate activity. The collective may also outsource the execution of activities and the management of jointly owned assets to one or more other (market) parties.

The process of purchasing collective assets, products and services is not in scope of U2DEMO. However, for activities that require the control of assets it is important to know the status of ownership and the agreements between the ownership about using the assets. This aspect covered in the category 'Collective control of individually or jointly owned assets'.

I.15 Domain transcending value

The category domain transcending value refers to activities that generate value both within the energy domain and in other societal domains such as the living environment or mobility. Examples include issuing vouchers for renewable energy generation that can be redeemed for discounts at local businesses or for shared mobility services, such as neighbourhood electric cars. Another example is the collective purchase of electric vehicles (EVs) by community members, where the vehicles serve a dual purpose—providing mobility while also functioning as temporary energy storage within the energy domain.

The process of bringing value from the energy domain to another domain (investments in biodiversity, playgrounds, e-mobility and health) is not in scope of the U2DEMO project and was for this reason not further worked out.

We identified that activities making use of voucher provision for consuming energy within the community can be implemented as the activity 'energy sharing via cash-back model' as the cash-back can come also in the form of a vouchers for local food or e-mobility kilometres with a community-owned car.