Recommendations for customer engagement strategies

D11.5

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About OneNet

The project OneNet (One Network for Europe) will provide a seamless integration of all the actors in the electricity network across Europe to create the conditions for a synergistic operation that optimizes the overall energy system while creating an open and fair market structure.

OneNet is funded through the EU's eighth Framework Programme Horizon 2020, "TSO – DSO Consumer: Large-scale demonstrations of innovative grid services through demand response, storage and small-scale (RES) generation" and responds to the call "Building a low-carbon, climate resilient future (LC)".

As the electrical grid moves from being a fully centralized to a highly decentralized system, grid operators have to adapt to this changing environment and adjust their current business model to accommodate faster reactions and adaptive flexibility. This is an unprecedented challenge requiring an unprecedented solution. The project brings together a consortium of over seventy partners, including key IT players, leading research institutions and the two most relevant associations for grid operators.

The key elements of the project are:

1. Definition of a common market design for Europe: this means standardized products and key parameters for grid services which aim at the coordination of all actors, from grid operators to customers;
2. Definition of a Common IT Architecture and Common IT Interfaces: this means not trying to create a single IT platform for all the products but enabling an open architecture of interactions among several platforms so that anybody can join any market across Europe; and
3. Large-scale demonstrators to implement and showcase the scalable solutions developed throughout the project. These demonstrators are organized in four clusters coming to include countries in every region of Europe and testing innovative use cases never validated before.

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List of Abbreviations and Acronyms

Acronym	Meaning
ACER	Agency for the Cooperation of Energy Regulators
API	Application Programming Interface
BAS	Building Automation Systems
BSP	Balancing Service Provider
CEC	Citizen Energy Community
CEP	Clean Energy for All Europeans Legislative Package
DR	Demand Response
DSF	Demand Side Flexibility
DSO	Distribution System Operator
EC	European Commission
EII	Energy Intensive Industries
EMS	Energy Management System
ENA	Energy Network Association
ESCO	Energy Service Company
EU	European Union
EV	Electric Vehicle
FSP	Flexibility Service Provider
GDPR	General Data Protection Regulation
GHG	Greenhouse Gas
GO	Guarantee of Origin
IEMD	Internal Electricity Markets Directive
IT	Information Technology
LV	Low Voltage
MS	Member State
P2P	Peer-to-Peer
PPA	Power Purchase Agreement
PV	Photovoltaic
QoS	Quality of Service
R&D	Research and Development
RD&I	Research, Development and Innovation
REC	Renewable Energy Community
REDII	Renewable Energy Directive II
RES	Renewable Energy Source
SME	Small and Medium Enterprise
SO	System Operator
T	Task
TAM	Technology Acceptance Model
ToU	Time of Use
TSO	Transmission System Operator
WP	Work Package

Executive Summary

The electricity sector is currently undergoing a transformative change, whereby flexible resources, especially those at the level of energy customers, are gaining an increasingly important role. This deliverable delves into the barriers to customer engagement in flexibility markets and provides recommendations to overcome them. By removing these barriers, stakeholders can unlock the untapped potential of flexibility at the customer level and create an environment that promotes active customer participation, leading to a more customer-centric power system.

The research conducted for this deliverable was primarily based on an extensive literature review that explored customer engagement in various areas, including the adoption of environmentally friendly behaviour, switching energy tariffs, participation in energy conservation programmes, and engagement in demand response programmes. Interactions with OneNet cluster demonstrators constituted an important part of the work activities. One of the key findings was the identification of four groups of barriers to customer engagement in flexibility markets: economic, behavioural, legal, and technical barriers. The recommendations for customer engagement presented in this deliverable are designed to address these specific barriers.

For the purpose of this research, eight main groups of customers were identified, i.e., residential and groups of residential customers, small and large commercial customers, small and large industrial customers, energy-intensive customers, and others. This segmentation enabled us to interact with the OneNet demonstrators in a clear and unambiguous manner and, where relevant, to provide recommendations more consistent with customers' needs and preferences.

Identified economic barriers to customer engagement in flexibility markets are the limited value of flexibility, the high level of risk and uncertainty, and current market and product design challenges. These barriers include the absence of economically viable business models, high upfront investments with uncertain returns, and limited potential for value stacking across markets. To address these barriers, we recommend supporting value stacking, reducing investment costs needed to enter the market, and promoting interoperability of devices through standards and open data. We also suggest providing customers with the freedom to choose their flexibility service provider and energy supplier, implementing tariff designs that support flexibility engagement, and increasing information availability to reduce economic risk and uncertainty. Conducting more research on the economic benefits of flexibility is also advised to strengthen the business case and encourage participation.

Identified behavioural barriers are a lack of awareness, a lack of skills to elaborate on information, and the status-quo bias. Customers have limited understanding of the benefits deriving from participation in flexibility markets and struggle to understand how their daily habits affect energy usage. To address these barriers, we recommend implementing effective engagement strategies based on customers' socio-economic and behavioural characteristics. Awareness campaigns tailored to specific customer groups, focused on economic

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aspects, environmental issues, and technological innovation, are recommended as well. Collaboration between the public and private sector is crucial for resource allocation and achieving desired outcomes. Clear and simple communication about flexibility-related offers, personalised feedback on results, and measures to overcome the status-quo bias and build trust are also important. Contracts should consider customers' needs, provide opt-out options, and establish minimum customer protection measures.

Identified legal barriers are exclusion of certain customers and market operators from flexibility markets, the existence of contractual constraints and burdens, privacy and data access issues, and a lack of a regulatory framework promoting standards and interoperability. Regulatory limitations on customer participation, complex regulations, and restrictions on energy communities and peer-to-peer energy trading platforms contribute to market exclusion. To address these barriers, we suggest promoting competition and customer choice by enabling independent aggregators and preventing hindrances by existing suppliers. Fair and efficient pricing mechanisms and measures to prevent market manipulation are needed to protect customers from high wholesale electricity prices. Fair, efficient and transparent contracts, which are also easy to terminate and/or switch, are recommended, along with privacy protection measures that comply with general data protection regulations. Standardisation and interoperability are crucial for implementing flexibility solutions; eliminating ambiguities in the law and industry standards can provide clarity and guidance. Digitalisation, data access, and blockchain technology can support customer engagement and transparency.

Identified technical barriers are related to a lack of infrastructure and harmonised architecture, data exchange challenges, and interface design and communication issues. Infrastructure limitations, such as the absence of smart meters and energy monitoring systems, pose challenges to customer participation. Data exchange barriers include planning only for one-way data flows, a lack of communication standards, and limited consent mechanisms. To address these barriers, we recommend equipping smart meters with robust functionalities, enabling two-way communication between system operators and customers, and prioritising infrastructure design for reliability, scalability, and cost-effectiveness. Transparent consent mechanisms and unified interfaces with industry-wide standards are advised for data exchange. Training and capacity building are needed for handling large data volumes, while user-friendly platforms, consistency in design, and automated solutions simplify customer participation. Open-source solutions, good communication, education, and support can enhance user experience and facilitate integration.

The deliverable presents the barriers to customer engagement and provide recommendations based on a high-level assessment and may not fully account for the specificities of individual system service markets. The analysis and recommendations were informed by the experience gained from the OneNet demonstrators, but the limited number of real customers involved and the simulated market functioning somewhat constrained the findings. To strengthen the conclusions on customer engagement provided in this deliverable, we suggest to increase the collection of empirical evidence by involving more customers in future on-field projects.

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1 Introduction

The carbon neutrality goals set by the EU Green Deal and the development of renewable and digital technologies are forcing a structural change in the operation of the power system. The increasing penetration of renewable energy sources is changing the dominant paradigm, in which energy production follows demand: in the future, it is likely that demand will have to adapt to the available supply of a mostly intermittent energy supply. In this scenario, the end customer, be he or she a household or an industrial firm, will play an increasingly important role in ensuring system balance. However, in order to bring the transition process to fruition, it is necessary for the customer to accept new technologies, new market mechanisms, and new energy usage patterns. This means engaging customers and making them more aware of the change.

Customer engagement in energy-related issues is not a new policy area nor a new research topic. However, little progress has been achieved in this area so far: nowadays most customers remain disinterested in energy-related issues and unaware of the new existing (economic) opportunities provided by the digitalisation, decarbonisation and decentralisation of energy systems. Moreover, the development of flexibility markets creates new challenges related to customer engagement. In the current context, the main open issues are the development of market-based solutions that benefit the overall system but also generate added value for customers, and how to make customers aware of this, e.g. how to effectively convey complex information and make it easy to act on it. This implies that when analysing the issue of customer engagement, one must not only look at the behavioural dimension of the customer but also at the wider context in which he or she operates. This can include economic, technical, and legal elements that enable or hinder the engagement process. In order to engage customers and create consumer-centric flexibility markets, it is therefore necessary to understand what barriers are hindering this process and how to act on them.

In light of this, a few main points can be identified:

- customer engagement analysis must take into account the specific type of customer you want to engage and what the purpose of the engagement process is;
- effective engagement strategies must reflect customers' needs but also the context in which they operate;
- in order to successfully complete the engagement process, one must identify specific and clear barriers that prevent customers from participating in flexibility markets;
- customer engagement is a multidimensional process and therefore different actors can contribute to the engagement process. It must be borne in mind, however, that different actors act over different time horizons.

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1.1 Task 11.6 methodology

Task 11.6 - Recommendations for customer engagement strategies - explored the main barriers related to customer engagement in flexibility markets and proposed recommendations to overcome them. The task consisted of both theoretical and more empirical-based activities.

More specifically, three main types of activities were carried out (*Figure 1.1*): a literature review on customer engagement, a series of interaction moments with project partners and external actors, and the identification of barriers and provision of related recommendations.

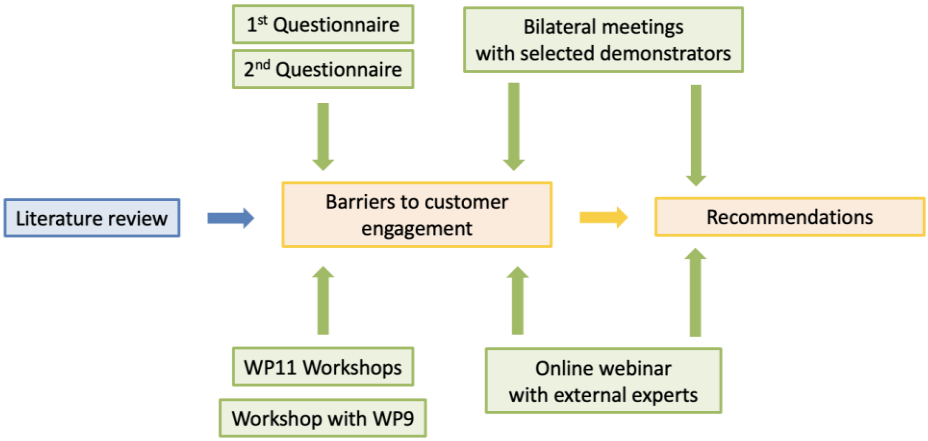

Figure 1.1 - Main activity streams within T11.6.

The aim of the literature review was twofold: 1) to collect inputs by other pieces of research and EU projects that dealt with issues related to customer engagement, and 2) to develop a framework to set the scope of our analysis. In this regard, we explored not only the academic literature but also stakeholder reports and RD&I deliverables. The main output of our desk research was the identification of a framework to analyse the main barriers that hinder customer engagement (see Chapter 3).

Two kinds of interaction moments were organised in the framework of T11.6: the "internal interaction moments" were focused on OneNet project's participants, while the "external interaction moments" involved stakeholders and experts outside the project.

Within the internal interaction moments, we submitted two questionnaires to OneNet project's participants, and we took part in the OneNet WP3-WP11 Regulatory Workshop[1] and in the 3rd WP11 Workshop[2]. The first set of questions was provided within the framework of the WP11 Regulatory Questionnaire and was submitted to

[1] Online event organised on 15th November 2022.
[2] Online event organised on 31st March 2023.

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all demonstrators' representatives. The questions aimed to identify the types of customers engaged in the OneNet project and the main regulatory barriers related to customer engagement that project partners had met (see Appendix 7.1). Questionnaire results were integrated and validated via the OneNet WP3-WP11 Regulatory Workshop and a series of bilateral meetings organised with the partners involved in the different demonstrators in January 2023. A second questionnaire was produced in accordance with our analytical framework on barriers to customer engagement. The second questionnaire was submitted only to the project demonstrators who had successfully engaged customers by January 2023, and aimed to explore the main barriers experienced by aggregators and customers themselves during the engagement process (see Appendix 7.2). For this reason, we submitted a specific questionnaire for aggregators and another one for customers (each questionnaire was translated into the relevant national language). We organised a bilateral meeting with some representatives of the Spanish and the Cypriot demonstrators in order to integrate the questionnaires' results. Our contribution to the 3rd WP11 Workshop aimed to present our framework on the barriers to customer engagement and collect feedback from other project's partners. We collected feedback from workshop participants through a poll and by listening to the reactions of cluster leaders.

Within the external interaction moments, we organised two online events: a workshop[3], co-hosted by E-REDES, the leader of WP9 (Western cluster), and a webinar[4]. The workshop aimed to introduce flexibility issues mostly to a Portuguese audience of industrial customers and collect their feedback for our analysis of the barriers to customer engagement. These inputs were gathered through two polls specifically targeted at the Portuguese customers who attended the workshop. More specifically, the first poll addressed behavioural barriers, the second one addressed economic barriers. The webinar was organised to collect insights from some experts external to the project; these insights were used during the internal brainstorming for the analysis of barriers and the production of recommendations.

The proposed recommendations are based on the inputs from the literature review, our analysis of barriers and the demonstrators' experience observed within the OneNet project.

1.2 Objective of the work reported in this deliverable

This report was produced within the framework of WP11, whose objective is to analyse the achievements of the project demonstrators and extract conclusions which can be implemented at the EU level. More specifically, the goal of T11.6 is to provide recommendations for customer engagement in flexibility markets. In this regard, the task analysed what kinds of customers were engaged in the OneNet project and the main barriers experienced in the different demonstrators to engage them. This empirical analysis allowed to integrate the

[3] Online event organised on 2nd May 2023. Recording is available at: https://www.youtube.com/watch?v=AenbrapV1LI.
[4] Online event organised on 9th May 2023. Recording available at: https://www.youtube.com/watch?v=_KD7Ko44FwI.

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theoretical analysis developed within the Task and to produce recommendations for customer engagement following an evidence-based approach. In order to provide recommendations that can be valid beyond the OneNet project's boundaries, we considered it essential to develop an analysis method which was evidence-based, yet consistent with academic and theoretical knowledge on customer engagement. This method aimed to verify: 1) the applicability of our analytical framework, and 2) if we could identify further barriers to customer engagement that have not been found during the desk research. Lastly, the provision of recommendations was the core activity of T11.6. The main goal of this activity consisted of proposing a clear set of recommendations that allow the barriers identified within T11.6 to be overcome. These recommendations represent a toolkit for policy makers, regulators and market operators, who are facing issues related to customer engagement in the EU electricity markets. It is worth specifying that our recommendations do not purport to offer a definitive solution to the issues of customer engagement in flexibility markets. In fact, our recommendations are limited to the barriers we identified during our desk research and the interactions we were able to establish with cluster demonstrators who successfully engaged customers. Therefore, further research on how to effectively engage customers in flexibility markets is needed.

1.3 Outline of the deliverable

This deliverable is composed by four main chapters and two appendices.

Chapter 2 sets the scope of our analysis, providing the definitions of customers, engagement, and an overview of the literature on the topic of customer engagement in the power sector.

Chapter 3 explores the main barriers to customer engagement in flexibility markets and presents the four groups of barriers identified in our analysis (economic, behavioural, legal and technical). Dedicated boxes provide additional insights regarding the specific case of energy communities and industrial customers and the results of our interaction moments.

Chapter 4 provides recommendations to overcome the barriers identified in Chapter 3.

Chapter 0 concludes the deliverable with the main takes on customer engagement in flexibility markets and open issues.

Two appendices provide the text of the questionnaires we submitted to the OneNet cluster demonstrators.

1.4 How to read this document

Reading this deliverable requires a minimal knowledge of the functioning of electricity markets in the EU. Moreover, this deliverable builds on the results achieved by other tasks of the OneNet project. Therefore, in the

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following, we show how this task interacts with other OneNet tasks and the OneNet deliverables we recommend to read in order to fully benefit from the reading of this deliverable.

As shown in *Figure 1.2*, this task builds on the definition of consumer-centric products and market design developed in WP2 and WP3, and the identification of interfaces and technical requirements for customer participation in WP4 (Task 4.3). Furthermore, this task extracts results from demonstrators in which customer involvement plays a key role.

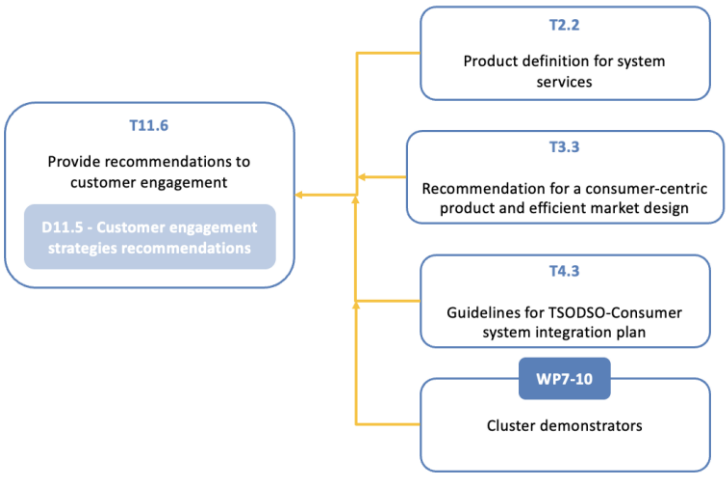

Figure 1.2 - Interactions between Task 11.6 and other work packages in OneNet.

Among the project deliverables that were published before the publication of this deliverable, we recommend reading the following ones:

- deliverable 2.2[5], which elaborates a theoretical framework for products building on the discussions on systems services and products developed in previous research and innovation projects;
- deliverable 3.2[6], which aims to identify the missing components needed to build integrated and fully coordinated markets for the procurement of the harmonised products;
- deliverable 4.3 [7], which provides a customer-centric perspective for the data exchange and communication in the interaction between transmission system operators (TSOs), distribution system operators (DSOs), market operators and customers.

[5] Available at: https://onenet-project.eu/wp-content/uploads/2022/10/D22-A-set-of-standardised-products-for-system-services-in-the-TSO-DSO-consumer-value-chain.pdf.
[6] Available at: https://onenet-project.eu/wp-content/uploads/2023/04/D3.2_OneNet_v1.0.pdf .
[7] Available at: https://onenet-project.eu/wp-content/uploads/2022/12/OneNet_D4.3_v1.0.pdf.

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2 State of the art on customer engagement

2.1 Definition of customer and customer engagement

In order to clearly identify the object of our analysis, this section provides some fundamental definitions. Section 2.1.1 is dedicated to the definition of "customer" and to the description of the segmentation strategy adopted in this deliverable. In this regard, customers engaged in the OneNet project are also identified. Moreover, two boxes provide an insight into energy communities and industrial customers, which will be specifically analysed in the chapters on barriers and recommendations. Section 2.1.2 offers an overview of the evolution of the definition of "customer engagement" and clarifies what is its meaning in the framework of Task 11.6.

2.1.1 What is a customer?

As a first step in our analysis, we clarified a potential semantic issue. It can be observed in the literature that the terms "consumer" and "customer" can be used quite interchangeably. The main difference is semantic in nature: the term "consumer" emphasizes aspects associated to the physical usage of energy, while "customer" is more related to the economic implications of energy consumption [1]. For the sake of simplicity, in this report we will use only the term "customer".

Customers can be defined as value-maximising economic actors, within the bounds of (their) search costs and limited knowledge, mobility and income [2]. This definition offers a first clue when speaking of customer engagement: in order to engage customers, they have to identify or perceive a clear value (a benefit) in being engaged. Moreover, customers are not necessarily monolithic entities, but their characteristics (i.e., what they perceive as a benefit and the related constraints mentioned above) may change over time. This suggests that engagement strategies should change following changes in the customers' life. However, the definition above does not imply that all customers are the same. Rather than customers, it would be correct to speak of different types of customers. Essentially, every customer is different but, for analytical and operational purposes (e.g., providing recommendations), it is possible to identify different groups (or types) of customers. In this regard, it can be more convenient to segment customers according to common characteristics that are shared within the same group [3]. A group of customers can be defined as a bundle of customers that share some determinant characteristics which allow to recognise a common pattern in energy utilisation.

A universally valid segmentation of customers does not exist, and different solutions have been proposed in the literature according to the analysis' scope. For instance, a segmentation can be based on different approaches on using and buying electricity or on producing it, and allows, for example, to distinguish among consumers and prosumers. In this regard, Kubli et al. identify four main groups of customers according to their

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preferences on energy utilisation: conventional consumers, conventional prosumers, demand response and flexible prosumers [4]. Socio-economic characteristics offer a valid method to segment customers: according to this strategy, customers are classified based on their primary economic activity and social role (e.g., a residential customer or an industry). However, it is worth to mention that we should not forget that customers which belong to the same group can be characterised also by different psycho-sociological factors, such as needs, preferences, moral values, etc.

For the purpose of this research, we identified eight main groups of customers:

- Residential customers (e.g., individual households),
- Group of residential customers (e.g., multi-apartment blocks),
- Small commercial customers (e.g., shops and restaurants),
- Large commercial customers (e.g., hotel and office buildings),
- Small industrial customers (e.g., light manufacturing),
- Large industrial customers (e.g., big manufacturing)
- Energy intensive customers (e.g., steel and paper-making plants)
- Others.[8]

This segmentation allowed us to interact with the OneNet demonstrators in an unambiguous way. In this regard, *Figure 2.1* shows the groups of customers that were engaged in different OneNet demonstrators.[9]

[8] The same groups of customers can be classified according to the voltage level they are usually connected to. Residential customers, group of residential customers and small commercial customers are usually connected to the low voltage level. Large commercial customers and small industrial customers are usually connected to the medium voltage level. Large industrial customers and energy intensive customers are usually connected to the high voltage level. This difference has an implication on the role each group of customers can play in the power system.

[9] These results have been collected through the first questionnaire and the related bilateral meetings. Information then reflects the situation at the beginning of 2023. OneNet demonstrators that do not appear in the figure did not have engaged any customers at that time.

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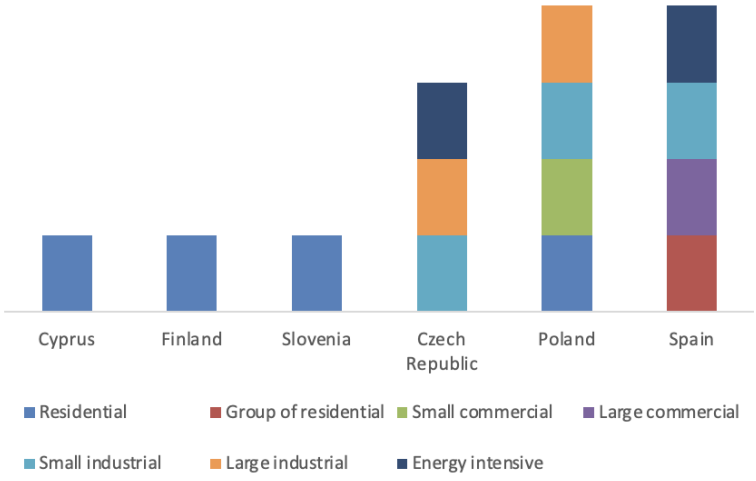

Figure 2.1 - Groups of customers engaged in the OneNet project.

Box 2.1 - Energy communities.

Customers can engage in the energy sector either individually or by joining some form of collective action. The second option refers to what is usually defined as an energy community or a community energy project. Energy communities are very heterogeneous and can perform different tasks in the energy sector, including the provision of flexibility [5]. The EU has recently introduced a legal framework for energy communities. This box provides the definition of renewable energy communities (RECs) and citizen energy communities (CECs), as introduced in the EU legislation, and touches upon their engagement in flexibility markets.

In the Clean Energy for All Europeans Legislative Package (CEP), the EU has signalled a strong shift in the role of citizens from passive consumers to active participants in the energy transition. For the first time, EU legislation acknowledged the role communities can play in helping the EU meet its climate and energy objectives while driving local social innovation. In particular, the REDII and the IEMD introduced provisions for RECs and CECs respectively, giving them a set of rights to participate across energy markets, and requiring a national enabling framework to help them develop [6][7].

Both definitions are composed of a set of criteria, or "principles-based" elements, that must be met in order for an entity to be considered an energy community. The starting point for both definitions is the establishment of a legal entity. Furthermore, the legal entity must be organised around specific ownership and governance principles, and has a non-commercial purpose. Together, the elements of both definitions convey a similar concept: a particular way to organise collective ownership around a particular energy-related activity. Therefore, some of the elements in the REC and CEC definitions are identical, or very similar [8].

The participation to a REC is open to natural persons, local authorities, including municipalities, and small and medium enterprises (SMEs), while CECs are based on open and voluntary participation as well and are

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effectively controlled by members or stakeholders that are natural persons, local authorities, including municipalities, or small enterprises. Therefore, energy communities are a vehicle for citizens and local actors to actively engage and participate in the energy transition. Energy communities have the potential to operate across the market and they can undertake several activities, including renewable energy production, supply, storage, aggregation and flexibility services.

Participating in the provision of flexibility services is a new opportunity for energy communities, which can actively support the operation and management of the electricity grid and help reduce the investment needed to integrate an increasing amount of distributed energy resources, while generating additional revenue streams for members [8]. Currently, only a few energy communities are experimenting with the provision of such services. Among the existing initiatives, it is possible to mention Energie Samen (Netherlands) and Energent (Belgium), which are experimenting with aggregation to offer services to system operators, while Partago (Belgium) is experimenting with peak-pricing supported by home batteries and electric vehicles, both avoiding charging during the most expensive hours [8]. In the FLEXCoop project, Som Energia experimented with the automation of residential appliances, such as heating and air conditioning, to optimise the purchase of electricity in the day-ahead market [8].

The existence of some barriers on the way of these community initiatives can explain the limited role they currently play. More information about these barriers is provided in Chapter 3.

Box 2.2 - Industrial customers.

The industrial and commercial sector plays a fundamental role in Europe's economy. Industrial products and services represent more than 20% of the EU's total value added [9].

For simplicity, industrial customers can be distinguished in:

- Energy-intensive Industries (EII),
- Other large industries,
- Small and medium enterprises (SMEs).

Grouping of industrial and commercial customers based on energy intensity can provide valuable insights into energy consumption patterns and enable more efficient customer engagement. This clustering can optimise subsequent engagement, by helping in structuring targeted consumer strategies with relation to demand response and other energy flexibility provisions and services. By categorizing them into three distinct clusters, we can better understand their specific needs and tailor interventions accordingly [10].

The first cluster comprises energy-intensive industries. These are sectors characterized by high energy consumption due to their production processes, such as steel manufacturing, chemical production, or cement

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plants. These industries often have complex energy requirements and are major contributors to the overall energy demand of a given economy. Clustering them together allows policymakers and energy providers to focus on implementing energy-saving measures and exploring cleaner alternatives to reduce their environmental impact.

The second cluster consists of large companies that are not energy intensive. These are typically organizations with significant operations and energy needs but which do not belong to energy-intensive sectors. Examples could include large retail chains, financial institutions, or technological companies. Understanding their energy consumption patterns helps identify opportunities for energy efficiency improvements and renewable energy integration, contributing to both cost savings and sustainability goals.

When it comes to large companies, both energy intensive and non-energy intensive, two key elements in consideration for implementation of demand response and flexible energy systems are:

- Firstly, operational constraints. Large companies often have complex and continuous manufacturing processes that require a steady and uninterrupted supply of energy. These processes may involve high-temperature operations, chemical reactions, or other specialized requirements that cannot be easily interrupted or adjusted. A perception is that implementing demand response and smart energy solutions may introduce variability in energy supply, which can disrupt production schedules and lead to quality control issues.
- Secondly, cost-benefit analysis practices. Energy-intensive industries typically have high energy consumption and their energy costs form a significant portion of their overall operational expenses. While demand response and smart energy solutions have the potential to optimize energy usage and reduce costs in the long run, the initial investment required for implementing these technologies can be substantial. The installation of advanced monitoring and control systems, the retrofitting of existing equipment, and the training of staff to manage these new systems can involve significant upfront costs. Industries may be hesitant to invest in these solutions if the expected benefits in terms of energy savings and cost reductions are not clearly demonstrated or if the payback period is too long. For less energy-intensive companies, the outcomes of cost-benefit analysis can be even less advantageous than for energy-intensive industries.

The third cluster of industrial customers represents small and medium-sized enterprises (SMEs) that are not energy intensive. SMEs play a crucial role in the economy and often have unique energy requirements compared to larger companies. This cluster could encompass businesses in sectors like hospitality, retail, or professional services. By clustering them together, policymakers and energy providers can focus on tailored outreach programmes, providing targeted support and incentives to help SMEs adopt energy-efficient practices and technologies, which can lead to reduced energy costs and improved competitiveness.

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2.1.2 What is customer engagement?

Although the concept of customer engagement was first introduced in the 1990s, over time this concept has changed according to the evolving understanding of customer engagement behaviour and the changing technological context [11].

Table 2.1 offers a concise representation of the evolution of this concept up to the present day.

Table 2.1 - Development of customer engagement behaviour concept in marketing. Source:[11]

	Mid-1990s to mid-2000s	**Mid-2000s to mid-2010s**	**Mid-2010s to today**
	Functional	**Relational**	**Transformational**
Approach to engagement behaviour	Firm initiated/Short-lived effect	Customer initiated/Long-lived effect	Customer and firm initiated/Dual effect
Theories	Exchange theory, equity theory	Social exchange theory, S-D logic	Social network theory, service ecosystem
Key trends and disruptions	Customers consider valuable assets and firms try to enjoy this resource for competitive advantage; however, it has a transactional and short-term approach to engagement.	Customers consider value co-creator and relationships facilitate engagement formation; however, it requires a long- term investment in the relationship with customers.	New technologies i.e., social media, mobile apps, augmented and virtual reality transform interactions between customer—firm—other actors in a network of interaction.
Key insights	Monetary incentives encourage the customer to contribute to firm marketing activities such as referring to a new customer.	Customer-firm dyadic relationships over time encourage the customer to engage with the firm.	Technology empowers the customer to engage with the firm and other actors and enables firms through firm-initiated engagement activities and directly influence an actor's engagement behaviour.

According to Brodie et al. (2011) customer engagement is "a motivational state that occurs by virtue of interactive co-creative, customer experiences with a focal agent/object (e.g., a brand) in focal service relationships. It occurs under a specific set of context-dependent conditions generating differing customer engagement levels; and exists in a dynamic, iterative process of relational exchange that cocreate value. […] It is a multidimensional concept subject to a context- and/or stakeholder-specific expression of relevant cognitive,

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emotional and/or behavioural dimensions" [12]. However, according to Brodie et al. (2019), recent developments suggest the need to broaden the conceptual domain of customer engagement to a general actor-to-actor perspective, i.e. to relationships between multiple actors in service ecosystems[10]. In this regard, the authors define actor engagement "as a dynamic and iterative process that reflects actors' dispositions to invest resources in their interactions with other connected actors in a service system" [14]. What is important to note for the purposes of our analysis is that customer engagement is a multidimensional concept that is inextricably linked to customer experience [15]. More specifically, different levels of customer engagement can be measured by the level of cognitive, emotional, and behavioural investment of customers in specific interactions [16].

Looking more specifically to the power sector, the meaning of customer engagement can differ in the perceptions of different customers. For some of them, it means to switch energy supplier with a certain degree of regularity or even for the first time. For others, customer engagement relies on the utilization of comparison tools, adapting consumption to real-time prices or to the availability of energy produced by themselves. Finally, submitting a complaint to a supplier when the quality of service is too low is an additional form of engagement [17]. Moreover, the meaning of customer engagement changed over time. In fact, renewable generation spreading and the related growth in need of flexibility for the system increase the opportunity for an increasingly wide range of customers to participate in flexibility markets. In this regard, an additional meaning of customer engagement can be associated with the decision to take advantage of the new economic opportunities that are made available by the evolution of electricity markets. Engagement in flexibility markets represents a new form of customer engagement and is the interpretation of customer engagement adopted in this deliverable.

2.2 Summary of the literature on customer engagement

Customer engagement in the electricity sector is a subject that has garnered significant attention in both academic and non-academic literature. This section aims to provide a comprehensive review of the topic, highlighting key aspects relevant to customer engagement in the electricity sector. The discussion encompasses behavioural aspects of customers but also techno-economic elements that can hinder or enable the customer engagement process. The concept of customer engagement can vary in meaning and application across different contexts. This deliverable focuses on exploring customer engagement in areas such as the adoption of environmentally friendly behaviour, switching energy tariffs, participating in energy conservation programmes, and engaging in demand response programmes. According to our literature review, these areas have received the most attention to date with regard to customer engagement in the electricity sector. While each of these

[10] According to Vargo and Lusch (2016), a service ecosystem is defined as 'a relatively self-contained, self-adjusting system of resource-integrating actors connected by shared institutional arrangements and mutual value creation through service exchange' [13].

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areas has its own unique characteristics, there are recurring elements that hold relevance for customer engagement in flexibility markets.

Understanding customer behaviour and effectively segmenting customers is crucial for successful engagement. The process of customer segmentation involves observing and comprehending customer behaviour, which in turn helps in developing effective strategies. However, it is essential to exercise caution when employing different methods for customer segmentation, as some approaches may lack methodological and statistical transparency. Two primary schools of thought can be distinguished in this regard: psychology-oriented approaches that focus on individual decision-making, and sociology-oriented approaches that emphasise the influence of social structures on individuals. Efforts have been made to bridge these perspectives through theories like practice theory and social transitions theory [18]. Irrespective of the chosen segmentation strategy, identifying the key motivational factors that influence customers' energy usage choices is paramount. These factors can vary depending on the purpose of the analysis, but often include considerations such as cost reduction, environmental concerns, and comfort. Understanding these factors helps in tailoring engagement strategies to effectively address customer needs [19].

To trigger behavioural change, customers need to be aware of their energy usage patterns, their impact on the environment and energy security, and how they can achieve energy and economic savings. While the installation of smart technologies and the provision of detailed information are important, they alone are not sufficient [20][21]. Feedback is valuable but needs to go beyond mere information provision and acknowledge the broader social and cultural influences on household energy use. Engaging customers successfully requires building trust, leveraging motivations and values, and placing customers at the centre of engagement strategies. Trust is a crucial prerequisite for customer cooperation and goodwill. Additionally, successful customer engagement involves iterative steps that allow for continuous observation and adaptation based on customer feedback [19]. Search costs can prevent the benefits of informed decision-making from materialising [22]. Residential customers who have never had the power to choose may not actively seek alternative, lower-priced energy retailers. Moreover, customer inertia and loyalty to existing suppliers can prevent customers from switching, even when better options are available [23][1]. Overcoming these frictions requires motivating customers to thoroughly understand their bills, associated tariffs, and potential cost-saving measures. It is important to address comfort concerns and provide comprehensive guidance so that customers can make informed decisions without needing an in-depth technical understanding of electricity [24]. Customers perceive the evaluation of energy options as a time-consuming activity: smart grid technologies, market products, price and tariff signals are generally perceived as very complex, and knowledge of energy-related topics is currently confined and limited to certain customer groups. Moreover, additional perceived costs are associated with aversion to the loss of comfort and load control. Comfort is critical and should not be questioned or influenced

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unless it is incorporated into a comfort service package and the impact on the end user is remunerated accordingly [25].

The availability of new technologies is essential for enabling customers to shift their loads through new market platforms. However, the economic capacity and willingness of market participants and/or customers to invest in these technologies can be hindered by high costs [26]. Identifying factors that inhibit or promote the adoption of new technologies is important. The unified theory of technology acceptance suggests that the expected effort in using a new technology is a reliable indicator of acceptance [27]. Other factors, such as gender, age, and trust in others and institutions, also play a role. Concerns regarding privacy protection and data management may arise with the introduction of blockchain technology in energy system applications [28]. It is important to note that the adoption of demand response technologies alone does not guarantee customer behavioural change; it simply creates the possibility for it [26].

Economic incentives play a significant role in motivating customers to participate in demand response programmes and adopt new technologies [29]. Costs associated with participation, such as investments in new technologies and behavioural changes, should be adequately compensated to drive customer engagement. The economic challenges lie in generating enough revenue to cover expenses while ensuring a fair distribution of captured value between service providers and customers [30]. Pricing structures also impact the business cases for renewable technologies, smart metering equipment, and other decarbonizing modalities [1]. However, doubts remain regarding whether there are sufficient financial benefits for customers to motivate their engagement in potentially complex systems that require habit changes [28]. The emergence of independent aggregators and innovative retailers holds a relevant role in enabling a broader customer market access. These economic agents coordinate production and consumption decisions on behalf of customers, providing new services to both customers and the electricity grid. However, ensuring that transaction costs remain low is crucial to avoid compromising economic gains. Equally important are the avoidance of inefficiencies that can arise from the activities of these new market operators and the implementation of an adequate coordination with system operators. Governments and regulators should assess the likely impact of new business models on private and social welfare, particularly in terms of distribution problems and potential exclusion of low-income households [28].

Regulators play a vital role in creating fair, transparent, and competitive markets that foster customer engagement. Allowing new players, including those from other sectors like vehicle manufacturers and IT companies, to enter the market on an equal footing with the traditional players of the energy sector is essential. Regulatory approaches need to go beyond granting access to the grid or market and may require collaboration with regulators from other sectors. Existing market power of new entrants from other sectors can create barriers to competition, while energy incumbents can leverage their customer base and access to valuable information

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to restrict market entry to new players. These challenges must be addressed to ensure fair competition and innovation [31].

2.3 EU regulatory framework for customer engagement

In this section, we briefly discuss how the role of energy customers has changed over time within the EU regulatory framework. In fact, while earlier regulations focused on customers as passive agents in need of protection, the newer versions view them more as active market participants. However, many of the following measures are extensively analysed in other deliverables of the OneNet project and therefore the reader will be referred to the respective documents in order to avoid overlap.

The Second Electricity Directive (2003/54/EC) provides a first attempt to make customers more active actors. In fact, in addition to adopt customer protection measures and public service obligations, Member States were required to ensure eligible customers had the possibility to switch to a new supplier (art. 3) [32]. The Energy Efficiency Directive (2012/27/EU) attributed energy customers an even more active role [33]. In particular, it stated that network or retail tariffs had to enable demand response measures by end customers through the implementation of dynamic pricing, time-of-use tariffs, critical peak pricing, real-time pricing, and peak-hour rebates (Annex XI). Moreover, Member States were prompted to promote the engagement of demand-side resources in wholesale and retail markets, and to guarantee non-discriminatory treatment of demand response providers, including aggregators, by TSOs and DSOs. Finally, Member States were required to define technical modalities for participation of demand response in balancing, reserve, and other system services markets (art. 16).

More recently, the active role of customers has been further developed in the Clean Energy Package (CEP). The CEP brings forth provisions concerning dynamic pricing, access to the market by demand response, the involvement of aggregators and energy communities, and the oversight of TSOs and DSOs. Central to these market developments is the promotion of demand response, which is defined as “the change of electricity load by final customers compared to their normal or current consumption patterns in response to market signals, including in response to time-varying electricity prices or incentive payments, or in response to the acceptance of the final customer's offer to sell the reduced or increased demand at a price in an organized market, as defined in Article 2(4) of Commission Implementing Regulation (EU) No. 1348/2014, whether alone or through aggregation” (art. 2) [7]. As a result, customers are motivated to respond to market signals in a manner that aligns with short-term deviations from their typical consumption patterns. Additionally, the revised Electricity Directive mandates that Member States promote energy management services and guarantee the deployment of smart metering systems.

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Lastly, two recent initiatives have further promoted the role of customers as active players in the power system: the publication of the Framework Guideline on Demand Response by ACER and the publication of Communication COM(2023) 148 proposing to amend the Electricity Market Design Rules by the European Commission (EC). ACER's Framework Guideline sets out the main principles for the development of binding EU-wide rules on demand response. The new rules aim at fostering the participation of customers, storage and distributed generation (e.g., rooftop solar panels, electric vehicles) in wholesale electricity markets, as well at facilitating the market-based procurement of balancing, congestion management and voltage control services needed by system operators. Main areas covered by the Framework Guideline are general requirements for market access, principles for prequalification processes and for the coordination of market-based procurement of congestion management, voltage control and balancing services [34].[11] The EC proposal aims, among other, to empower customers by providing more alternatives in terms of solutions to energy use. In particular, the proposal aims to provide customers with a wider choice of contracts and clearer information before signing them. At the same time, customers will be able to opt for dynamically-priced contracts to take advantage of price variability. The proposal also aims to promote investment in renewable energy sources (e.g., PV and wind) and peer-to-peer energy trading and sharing [35].[12]

[11] Task 3.4 of OneNet project provides a more detailed analysis in this regard.

[12] A more specific analysis on the current legal gaps to promote customer engagement is presented in Section 3.3.

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3 Barriers to customer engagement

Multiple barriers hinder customer engagement in flexibility markets and call for dedicated actions by market operators, regulators and policy makers. This chapter aims to present and analyse these barriers and prepare the ground for the discussion of the possible recommendations that will occur in Chapter 4. In order to propose effective recommendations, the identified barriers were clustered into four main groups:

i. Economic barriers,
ii. Behavioural barriers,
iii. Legal barriers,
iv. Technical barriers.

Table 3.1 presents the four identified groups of barriers and the research questions we used to identify them.

Table 3.1 - Four groups of barriers to customer engagement and research questions.

Groups of barriers	Questions to confirm or not the existence of the barriers
Economic	Do customers and their intermediaries have the necessary economic incentives to engage? Is customer engagement economically viable? Is the market structure conducive to participation by customers?
Behavioural	Do behavioural characteristics of customers enable their engagement in electricity markets? Are limits to standard rational action and other biases preventing engagement?
Legal	Are customers allowed by law and sector regulation to engage in electricity markets? Do legislation and regulation allow customers to provide flexibility directly or via intermediaries? Is the configuration of rights and duties not blocking engagement?
Technical	Do customers and their intermediaries have the proper technologies to engage in electricity markets? Is the necessary technology/infrastructure available? Are the technology/infrastructure needed by the different actors operable in a seamless way?

In what follows, we address the four groups of barriers individually. The analysis of each group builds primarily on the results of the literature review and the interaction moments performed in the context of the task.

In order to produce a framework useful for the production of recommendations, each group of barriers was further divided into a series of sub-categories of barriers that minimise potential overlaps as much as possible.

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Dedicated boxes that discuss the specific case of industrial customers and energy communities are provided as well.

3.1 Economic barriers

When it comes to economic barriers, the questions to be asked are whether customers and their intermediaries have the necessary economic incentives to engage, if this engagement is economically viable and if the market structure is conducive to customers' participation.

The economic barriers can be divided into three main categories, namely, limited value of flexibility, risk and uncertainty, and market and product design. In the following sections, each category is explained and further split up into specific barriers.

3.1.1 Limited value of flexibility

This category of barriers is related to the fact that today the economic value of flexibility is rather limited, hence, consumers may not be sufficiently incentivised to participate in flexibility initiatives. The price of flexibility is often too small in relation to the costs that must be borne to offer it. Several reasons explain why flexibility may have such a limited value. First of all, there is a lack of economically viable business models for all ranges of prosumers (i.e., residential to industrial, small to medium size), which leads to the exclusion of certain customers as well as limiting the portfolio creation of aggregators. For instance, many business models found in the literature focus on very specific distributed energy resources that promise a significant flexibility potential as an individual asset. However, as typical load assets of residential end-users include a range of appliances with very limited flexibility potential as standalone assets, the incremental costs for enabling flexibility through demand response for these customers are high and, hence, such customers might not have a visible monetary benefit in these business models [36]. Then, there are the high upfront investments needed and market entry costs to be able to offer flexibility (e.g., investments to be able to monitor and control flexible resources), while the return on investments is uncertain [36][37][38]. Another barrier, for some customers, is the remuneration structure. As flexibility markets are not mature yet and FSPs are not able to estimate if it is profitable to join a flexibility market or not, remuneration for reservation (availability payment) with guaranteed revenues seems like a precondition to participate in flexibility markets [37][39]. Additionally, the potential of value stacking across different markets is still limited (e.g., market timings not aligned, market and supporting processes not aligned, etc.) [40]. Moreover, some consumers already optimize their flexibility according to wholesale market prices (e.g., commodity contracts based on wholesale prices or direct participation in wholesale markets). These consumers have fewer opportunities to participate in flexibility markets as the dynamics of wholesale prices are already integrated into the strategy of their flexibility resources [37][41]. Additionally, some consumers face high costs for alternative options when providing flexibility. Some flexibility resources, for instance, need to be

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replaced by another energy source upon flexibility activation (e.g., heat pumps delivering heat that cannot be cut off from operation without another heat source being introduced, the so-called "fuel switching"), facing a higher cost. In such cases, the volatility of different energy carrier markets needs to be considered and can impact the ability to place bids in flexibility markets [37]. Finally, participation in flexibility markets can have a negative impact on other energy cost components, such as grid tariffs or certain taxes and levies. Grid tariffs with a peak component can, for instance, discourage consumers to provide flexibility services as the provision of these services might result in higher peaks, leading to higher bills [42].

3.1.2 A risky business in an uncertain environment

The second category of economic barriers to customer engagement is related to the fact that providing flexibility today can still be considered a risky business in an uncertain environment due to a number of reasons. First, there is uncertainty and a lack of clarity surrounding the current business case for consumers to offer their flexibility (aggregated or not) to flexibility markets. Additionally, customers currently have a low level of knowledge and understanding of their own energy usage, grid-related issues and potentials for flexibility service provision [40]. More specifically, there is a lack of clear information about the opportunities flexibility markets can bring to customers. It is therefore difficult for customers to estimate future financial gains from flexibility markets as the quantity of the flexibility need, the expected prices and frequency of market calls and how these will evolve are not known [25]. Also, seasonal and year-to-year differences in flexibility demand and price volatility in flexibility markets add to the difficulty of evaluating whether participation is economically beneficial or not [37][40]. Another barrier is the fact that, for customers, it is very difficult to assess the actual benefits in relation to the potential impact (e.g., loss of comfort or impact on their business activity/processes) [37]. Finally, the allocation of costs and benefits and the coordination and split of incentives is not clear (e.g., among the aggregator and owner of flexible resources, among the participants of community-based flexibility initiatives) and can hence reduce the economic benefit of the individual providers, because the value of flexibility may already be low as explained in the previous section [43].

3.1.3 Current market and product design

The third category of barriers is related to the fact that the current market and product design for flexibility poses an economic barrier to open and fair competition. Several examples can be found in the literature. To start with, the administrative and transaction costs associated with participation in flexibility markets are too high in relation to the low financial benefit that can be derived. Administrative burdens and inefficient processes create the perception that market participation is too cumbersome [37][44]. One of the reasons for this is that flexibility provision is not a core activity for most (both industrial and residential) customers. Customers typically have very little knowledge and experience with flexibility provision and they are typically risk adverse [37]. Additionally, engagement in the provision of flexibility services involves the use of complex technology to

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automate energy use. The ability to create such complex energy systems and calibrate the data-sharing process may result in the exclusion of economically vulnerable groups as it requires time and financial investment in the learning and adopting process [45]. Then, when it comes to market design, the lack of uniform registration processes or platforms makes it more difficult for customers to access different markets as they have to understand and use different processes for these markets, also leading to duplication of information and requests. In addition, these access and registration processes (as part of the prequalification process) very often still lack automation and require manual interventions or requests per flexible resource, which constitutes a large administrative burden [46]. Additionally, specifically when looking at low voltage (LV) customers, it should be emphasized that there is no appropriate baseline methodology and process established. Quantifying the amount of flexibility (typically expressed as energy) delivered by LV customers is not straightforward, due to the stochasticity of residential consumption, the absence of appropriate data and the lack of an appropriate methodology for baselining of LV customers [25]. Hence, the difficulty of establishing baselines also makes it harder for these customers to access markets. Finally, regarding product design, a product is made up of several attributes which are defined based on technical and bid-related dimensions [47]. The values assigned to the product attributes can create barriers. For instance, a minimum bid size of one MW (the current standard for balancing markets), a long duration time or the symmetry of a product can make it harder for customers to participate as they cannot individually satisfy those requirements.

Box 3.1 - Questionnaire and workshop results on economic barriers.

This box aims to provide an insight on economic barriers to customer engagement based on the results of two different interaction moments organised in the framework of T11.6.

According to the aggregators answering the questionnaires, economic rewards promised to the final customer(s) for participating in the OneNet demonstrators were not sufficiently attractive to foster the engagement process and not all the facilities had the possibility to offer relevant flexibility potential. In this regard, it is worth mentioning that in the Spanish demo financial settlement for service delivery has not been implemented. Similarly, in the Cypriot demo, the market was simulated. Most of the aggregators who answered the questionnaires did not experience significant costs in getting access to the customers' data. Still, some investments were carried out to install the equipment needed for flexibility provision. According to the customers answering the questionnaires, the great majority of customers use electricity to cover most of their energy needs and own one or more devices that can be managed in a flexible way. According to the customers' perspective, economic remuneration was not particularly attractive. However, as mentioned above, no financial settlement for service delivery was implemented in the Spanish and Cypriot demos: customers did not experience any monetary gains or losses for participating in flexibility markets. Nevertheless, the questionnaires confirmed our analysis of economic barriers in terms of the most relevant

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economic concerns felt by customers. Moreover, no additional economic barriers have been mentioned in the survey compared to those identified in our literature review.

In the Workshop co-organised with WP9, 23 participants answered the poll, confirming the relevance for Portuguese customers of conflicting signals (e.g., constraints in the production process; see Box 3.3), revenue potential and risk aversion as economic barriers to engagements (the three options got a similar number of votes). Only two respondents provided no information on economic constraints. Although the poll cannot be considered robust from a statistical point of view, it suggested that it is not possible to identify a single economic barrier that is decisive for each type of customer: engagement strategies should consider the specific economic priority of different customers.

Box 3.2 - Economic barriers to engage energy communities.

This box analyses the main economic barriers hindering the energy community engagement process in flexibility markets. To start with, there is limited demand for flexibility, as most energy communities do not engage in flexibility markets due to its complexity and the fact that it is often hard to offer system services for the actors that deal with residential users because of small loads and fragmented protocols. This is also connected with high costs, as for flexibility to be effective, it requires device automation. Hence the installation costs of home automation put a burden on the formulation of any business model.

More broadly, energy communities face several challenges in acquiring, financing and maintaining a sustainable business model, which impacts the activities they engage in, including flexibility services. In more detail, community energy projects have unique characteristics that distinguish them from the structures and practices of other energy projects. These characteristics include, but are not limited to, a strong reliance on decentralised organisation, voluntary contributions from community members with limited prior experience in energy development and trust in collective investments. It also includes how energy communities organize themselves, their governance, non-commercial purpose and often their size. These differences make establishing financial viability and accessing third-party financing particularly challenging, especially for smaller projects [48].

In more detail, securing financing from traditional sources still presents a challenge for community energy projects, particularly those that require early-stage support [49]. Community energy projects below a certain size may not attract interest from commercial lenders since they come with increased bank transaction costs and offer a limited return on investment [48]. In addition, commercial banks generally lack knowledge and understanding of the concept of energy communities and are, therefore, less ready to offer tailor-made financial solutions [50].

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Moreover, the risk profiles of individuals and communities differ from those of private sector companies. In many countries, citizen-driven investment in renewable energy has been absent, as policy frameworks have typically not accounted for the risks that communities face when investing in individual projects. Coupled with the prospect of facing direct personal risks and exposure when investing, community members may be reluctant to invest upfront in community energy projects. Furthermore, many communities new to renewable energy development tend to develop standalone projects. Unlike companies with several projects in development, these communities are unable to spread risks across a portfolio of projects. Difficulties in securing funding and reliance on single projects means that these communities also have more trouble covering costs and expenditures incurred in the initial stages of project development. All these factors ultimately slow down the development of community energy projects [48].

Box 3.3 - Economic barriers to engage industrial customers.

This box analyses the main economic barriers that hinder the engagement of industrial customers in flexibility markets [9].

According to the segmentation of industrial customers proposed in Box 2.2, we identified relevant economic barriers for different groups of industrial customers. In this regard, it is worth mentioning that economic barriers for energy-intensive industries are less relevant, hence, this box is focused on SMEs.

SMEs are typically more vulnerable to market shifts and more reliant on key contracts and customers than large companies. The need to maintain profitability and competitiveness with limited resources can make it more difficult for SMEs to pay attention to energy efficiency and engagement in energy markets. A focus on day-to-day cash flow and limitations in accessing capital create challenges in justifying non-core business investments. This is especially the case for SMEs [51].

SMEs often have limited financial and human resources compared to larger companies. They may lack the expertise or funding necessary to invest in and adopt advanced energy management technologies and systems. The cost of implementing and maintaining interactive and flexible energy systems can be prohibitive for SMEs, making it challenging for them to actively participate.

Cost is a significant concern for SMEs. They may perceive demand response or on-site energy generation projects as expensive or financially risky. Initial investment costs, the length of the payback period, and the level of the return on investment may deter SMEs from taking action.

SMEs often require significant capital investments to upgrade equipment, machinery, or production processes to enable flexibility in energy consumption. Limited financial resources can be a significant barrier

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for production SMEs to adopt flexible energy systems, as they may struggle to allocate funds for such investments.

SMEs often operate in highly competitive markets, where managing risks and maintaining stability are critical. Engaging in demand response or flexible energy systems may introduce uncertainties or perceived risks associated with energy availability, reliability, or financial implications. SMEs are often more risk-averse than larger companies, making them hesitant to adopt new energy management practices.

3.2 Behavioural barriers

Customers' behaviour may conflict with participation in flexibility markets – for instance, certain energy consumption habits may not be compatible with flexibility provision or customers may lack awareness and interest in certain topics. The scope of this section is to offer a first introduction to the decision-making process of customers and then explore in more detail behavioural barriers to customer engagement.

Analysis of energy-related behaviours is not a new topic per se: a vast literature has been developed since the 1980s to identify the main drivers of energy consumption, in particular that of residential customers. Two main research streams can be identified: a first one focused on pro-environmental behaviours, such as sustainable consumption and energy conservation, and a second stream on the reaction of customers to the liberalisation of the power sector, which includes topics such as switching the energy retailer and the participation in demand response programmes. More recently, behavioural analyses of participation in flexibility markets have been included in this last stream of research [52]. Fieldwork has been conducted within several EU-funded projects, such as CoordiNet, Platone and ENFLATE.[13] Despite the specificity of the types of studies mentioned, many considerations on customer behaviour can be generalised.

This analysis of behavioural barriers is focused mainly on small customers, e.g., residential customers and SMEs. In fact, larger customers tend to have more experience in electricity markets and their decisions tend to be more rational and business-oriented [53]. In what follows, we will present the main features which characterise customer behaviour and then focus on the analysis of behavioural barriers for customer engagement.

According to standard (neoclassical) microeconomics, customer choices are rational and driven by the optimisation of individual utility under budget constraints. Preferences are given, i.e., explaining their formation is out of the scope of the theoretical framework. According to this view, producers and customers have stable preferences which they try to satisfy through market transactions. It is the customer choices which reveal

[13] The interested reader may find the results of these projects at the following links: https://coordinet-project.eu/; https://www.platone-h2020.eu/; https://enflate.eu/.

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information on the underlying preferences. For example, the acceptance or rejection of a technology to improve energy efficiency should only reflect a rational assessment of its costs and benefits. At most, market imperfections, such as asymmetric information or transaction costs, may hinder the adoption of cost-efficient technologies and divert the customer from making the optimal choice. Therefore, policy interventions cannot be deployed considering deviations from rational behaviour because they are ruled out by hypothesis. However, assuming customers can solve complex optimisation problems appears per se as false: real world choices are quite complex and, broadly speaking, customers do not have the competences and time to solve such problems in their everyday life [54]. Classical microeconomic theory is not completely consistent with the outcome of customers' choices because mere economic principles are insufficient for analysing and understanding customer energy behaviour. In fact, a large body of research has established that the observed behaviour of customers (and businesses) is apparently inconsistent with the cost-minimisation hypothesis [55].

Customers can be better described as cognitively limited agents or, as stated by Herber A. Simon already in 1955, they are boundedly rational agents [56]. In fact, customer rational behaviour is limited by access to information and the computational capacities that the customer possesses [57]. In order to deal with these limited capacities and limited time availability, customers make choices relying on mental short cuts and intuitions. Even though they are very useful by a practical point of view, heuristics expose the decision-making process to several cognitive biases [58]. Among those, one of the most relevant is the loss aversion bias, introduced by Kahneman and Tversky (1979) in their prospect theory [59]. Prospect theory is quite useful for predicting customer choices under conditions of uncertainty, which are the typical conditions of energy-related decision-making processes. In fact, it has been observed that agents evaluate losses and gains asymmetrically: in particular, losses outweigh gains, or, in other words, the utility related to a certain gain is lower (in absolute value) than the disutility related to an equivalent loss. In the specific case of participation in flexibility markets, customer perceptions can be influenced by different kinds of loss aversions, not only monetary. For example, in some kinds of contracts, customers may be worried about experiencing a loss in autonomy, if the degree of freedom in consuming energy is affected by the participation in the market, and losses in the level of comfort they are accustomed to. Moreover, if the customer is asked to disclose information, for example on energy consumption, loss of privacy can become one of the main concerns [60].

Another characteristic of customer preferences which defies classical microeconomic theory is the fact that preferences are not static, and their formation is driven also by sociological and psychological factors.

Exploring motivations, attitudes and values is an integral part of any analysis of customer behaviour, because they should be taken into account to design and implement effective engagement strategies. However, the approaches to the determinants of customer engagement in the literature vary widely, mainly due to the variety of engagement objects and contexts. The elements determining engagement are closely related to the object of engagement, but in general, it is possible to identify elements reflecting both the psychological and sociological

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dimensions. Psychological elements include customer attitudes towards environmental issues, perceived responsibility for their actions and perceived behavioural efficiency. For example, it is assumed that customers without environmental concerns are less willing to engage in sustainable consumption[14]. The perception of responsibility is an important factor in leading towards altruistic behaviour. Moreover, customers will be more willing to engage in sustainable consumption if they believe their actions can have a significant impact. From an engagement perspective, it is important to identify sociological elements because they can represent a way to change customer behaviours. In this respect, we can distinguish three main elements: the conditions for sustainable consumption (e.g., green product accessibility), the promotion of sustainable consumption (e.g., information on environmental issues) and the social environment. This last element has a strong impact on behaviour, because the opinion and behaviour of peers often become a stimulus or an obstacle to change [62]. Hargreaves and Middlemiss (2020) identify three distinct types of social relationships that shape the way customers engage with and use energy: relationships with family and friends, agencies and communities, and identity relationships [63].

In light of this analysis, it is safe to say that a customer decision process is quite complex, and it can be seen as a multi-stage process influenced by several elements. Furthermore, a decision made today may influence subsequent decisions made progressively in the long run. Therefore, evaluating alternatives can be difficult, time-consuming, and potentially stressful, particularly for a residential customer. The decision-making process often requires professional knowledge and skills to evaluate the variety of services and products available. In fact, these generally require high initial investments and have a long service life. Adaptations of energy behaviour and solutions are often necessary after purchasing energy products and services to achieve the best results [64]. Different models have been proposed to describe the decision-making process in more detail, for example the “five-stage model”, which consists of the following steps: 1) needs of recognition, 2) information search, 3) evaluation of alternatives, 4) purchase decision, 5) post-purchase evaluation [65][66][67].

Three main groups of behavioural barriers to customer engagement in flexibility markets can be identified:

1. lack of awareness,

2. lack of skills to elaborate on information, and

3. status-quo bias.

The lack of awareness can be described as the lacking perception or the misperception of the world, and, for the scope of our analysis, it is related to the lack of knowledge on opportunities deriving from participating in flexibility markets. The lack of skills to elaborate on information can be described as the lack of the cognitive

[14] Sustainable consumption is the use of products and services in ways that minimise impacts on the environment in order to meet the needs of present and future generations [61].

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tools necessary to process information and taking decisions. It is related to the ability of implementing the cognitive effort required to become an engaged customer. The status-quo bias represents a bundle of behavioural factors which can prevent or slow down the process of acquiring awareness and elaborate information because of the perceived fatigue in performing these activities. The status-quo bias affects the evaluation of expected gains and losses that derive from the participation in flexibility markets and the speed in accepting changes and new habits during the decision-making process.

3.2.1 Lack of awareness

Energy is characterised by a "derived demand", which means customers are not interested in its consumption for its own sake but because by consuming it via some device they can obtain the energy service they are interested in [68]. Although energy consumption is a persistent and inevitable aspect of life, it remains intangible and represents a relatively small portion of household expenses. In general, energy does not occupy a prominent position in the hierarchy of customer priorities. It poses a challenge for customers to comprehend how their daily habits directly impact their energy consumption, and it can be rational for them to refrain from investing time and effort into unravelling this uncertainty [69]. Moreover, household activities require combinations of multiple energy-using appliances (e.g., making breakfast: lighting, refrigerator, microwave): activity-based costs and usage information are often unavailable [70]. Numerous studies have provided evidence of the limited awareness and prevalent misconceptions regarding electricity usage and consumption among households across various countries. For example, White and Sintov (*ibidem*) show how perceived savings has a far greater impact on the acceptance of time of use (ToU) tariffs than the actual change in bills and on-peak usage during a pilot ToU programme. Enhancing customers' understanding of their electricity bills, prices, and costs could significantly contribute to reducing overall electricity demand. In fact, individuals who lack awareness about electricity tend to be slightly less receptive to receiving additional information on energy consumption and energy-saving techniques than those who are well-informed. One plausible explanation for this finding can be attributed to their limited knowledge, which hinders their motivation to seek and acquire information for enhancing their understanding [69].

3.2.2 Lack of skills to elaborate on information

Awareness is a necessary but not sufficient condition for customer engagement: customers need tools to elaborate on information and taking decisions. Due to the intricate, technical, and unfamiliar nature of numerous energy-related choices, only a small subset of knowledgeable customers may be able to gather and analyse the required information effectively, enabling them to make informed and rational decisions [64]. Search activities are perceived as a cost by customers. The theory of information economics recognises that information gathering has a cost that can be offset by customer gains, i.e., the customer's expected utility. According to that theory, rational customers will act based on incomplete information to the extent that

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additional information is costly to collect or if the customer has high confidence in his previous judgements. However, incomplete information may lead to different choices than a customer would make with complete information [71]. The aforementioned costs include the mental effort devoted to research, selecting information and integrating it with what it is already known. Obviously, perceived costs vary among customers according to their ability to undertake research, which is correlated with levels of existing knowledge (e.g., of the energy sector), education, etc. Acquiring information could also be related to monetary costs or to the opportunity cost of time spent searching. Furthermore, the volume of available information expands at a pace that surpasses the capacity of human decision-makers to allocate attention effectively, forcing them to prioritise certain information while discarding others. As a result, customers may face the challenge of selecting among various sources of information. Additionally, it is conceivable that certain external channels of information can serve as alternatives to one another or represent the entirety of available information as proxies. Limited knowledge of the various options and customer uncertainty are likely to be obstacles to market participation. With particular reference to retail switching, it has been observed that, although search costs have decreased over time, the proliferation of increasingly complicated tariffs has discouraged change [72].

In the most extreme cases, customers may be completely excluded from the knowledge of available new technologies or services, for example due to economic, cultural or age-related factors. This is relevant considering that a FSP or a SO can expect varying degrees of flexibility from customers. He et al. (2013) classified customer load into five types of loads, which contribute together to form the customer load mix: 1) storable loads, 2) shiftable loads, 3) curtailable loads, 4) base loads, and 5) self-generation [60]. One of the most accepted models to describe the willingness to adopt new technologies is the Technology Acceptance Model (TAM). According to the TAM, two main factors impact on technology acceptance: perceived ease of use and perceived usefulness. Extended versions of the TAM have found additional constructs which add explanatory power and capture individual experiences and beliefs about how the considered innovation would behave in relation to multiple social elements [73].

3.2.3 Status-quo bias

Based on experimental evidence, the status-quo bias has been described by Samuelson and Zeckenhauser (1988) as “doing nothing or maintaining one’s current or previous decision” [74]. Four potential reasons for the presence of the status-quo bias have been identified: 1) transaction costs, which refer to the inherent costs associated with deviating from the current state; 2) uncertainty in the decision-making process, which involves the costly efforts required to explore alternative options and their associated benefits; 3) cognitive misperceptions, such as loss aversion (endowment effect), anchoring, or bounded rationality; and 4) psychological commitment stemming from the perception of sunk costs or the desire to avoid regret. Among others, Blasch and Daminato (2020) present a literature review on the impact of loss aversion on electric

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appliance choices [75]. Multiple studies have demonstrated an inverse relationship between loss aversion and the efficiency level of household appliances, as well as the overall energy consumption within households. Specifically, customers with higher levels of loss aversion exhibit a reduced inclination to invest in energy-efficient home renovations and tend to require a relatively higher risk premium for such investments.

The status-quo bias can lead customers into a state of inertia which hinders and slows down the change of their status quo. This phenomenon has been observed in various decision-making processes, such as when customers consider switching suppliers. Multiple pieces of evidence indicate that customers tend to stick with their current provider even when better pricing options are available. Customer inertia can be attributed to factors such as underestimating potential financial savings, lack of confidence in new retailers, complicated switching procedures, and strong loyalty to existing suppliers. Additionally, complex energy tariff structures can add to customers' reluctance to make changes [1].

Lastly, loss aversion is positively correlated with the lack of trust, for example in institutions or market operators. In fact, a lack of trust can inhibit market engagement and increase inertia. Among others, Stenner et al. (2017) show how customers use trust and distrust as decision heuristics to guide their behavioural changes and that distrust may reduce their willingness to participate in direct load control programmes [76]. Disengaged customers are less likely to trust energy suppliers but, in general, it has been observed that customers trust energy companies less than those in other sectors, such as banks or construction companies. Moreover, for more vulnerable customers, lower levels of trust in engagement and the market, perceptions of difficulty, and stronger concerns about rising costs have been observed [77].

Box 3.4 - Questionnaire and workshop results on behavioural barriers.

This box provides insights into behavioural barriers to customer engagement based on the results of two different interaction moments organised in the framework of T11.6.

According to the aggregators answering the questionnaires, customers' behaviour represented one of the main challenges for the provision of flexibility services in the Finnish and Polish demonstrators. Most of the aggregators engaged customers which were already aware about the possibility to participate in energy markets to gain some economic benefits and had the digital and technical competences required to understand the main features of the project. Nevertheless, aggregators experienced a general scepticism (e.g., lack of trust) in their regards. In most cases, no behavioural changes have been requested from customers. According to the customers answering the questionnaires, 50% of customers felt comfortable with letting a third party to monitor and have control over energy consumptions. Most customers that answered the questionnaire were not reluctant to be engaged in the OneNet demonstrators and were not sceptical of the person who contacted them to participate in the project. Although not all of them were aware of the possibility of participating in electricity markets, almost all of them stated that they had the skills to

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understand the main features of the project. For most of them, the required changes in behaviour were not permanent. However, according to the bilateral meetings with the Spanish and Cypriot demonstrators, tests have been organised in order to minimise the impact of flexibility provision on customers' habits and daily-life. For instance, within the Cypriot demonstrator, the engaged customer allowed to steer just a battery. Moreover, in both the Spanish and Cypriot case, customers were already quite aware of energy-related topics and therefore questionnaires' results cannot be generalised to a more variegated population.

In the Workshop organised with WP9, 24 participants replied to the poll about behavioural barriers. 67% of them expressed their awareness about the possibility to participate in demand response programmes or projects related to the provision of flexibility but found this possibility too complex; 25% was not aware of such opportunity. The remainders believed no real opportunity exists. Although the poll cannot be considered robust from a statistical point of view, it suggests that even among (large) industrial customers the lack of skills to elaborate information is an important behavioural barrier to engagement.

Box 3.5 - Behavioural barriers to engage energy communities.

This box provides insights into the behavioural barriers that hinder engagement of energy communities in flexibility markets.

To start with, the lack of public awareness and understanding of community energy and its potential benefits represent a significant barrier to citizen engagement in energy communities [78]. The limited understanding and knowledge also apply to more complex issues like how flexibility markets work and how energy communities can actively engage in them.

To compound matters, there is widespread scepticism and lack of trust in joint investments and the possibility to combine public and private capital. The fact that people often expect individual actors or large energy corporations to lead the way in distributed energy resources represents an important barrier to engagement via energy communities [78].

The lack of trust is also connected to the general lack of social acceptance towards renewable energy. Some studies find that social acceptance is entangled in people's perception of different renewables (e.g., onshore wind) and general awareness of community energy. It is also highlighted that the lack of awareness and public discourse about energy communities entails that actors that are interested in such initiatives are to a large extent left to themselves to identify and understand their possible roles and benefits, which may hinder community energy from being inclusive, for instance in terms of gender [79][80].

Finally, the dominant culture of the individual to detriment of the sense of community does not align well with the establishment of community initiatives, and the adoption of the concept of energy communities by individual citizens. People's focus on private ownership, in line with capitalist ideologies, influences people's

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sentiments towards sharing economy and common ownership of assets. This lack of active participation of citizens in joint cooperation was identified by the COME RES project as an obstacle to the implementation of energy initiatives through bottom-up processes [78].

Box 3.6 - Behavioural barriers to engage industrial customers.

This box analyses the main behavioural barriers that hinder the engagement of industrial customers in flexibility markets.

The behaviour of managers and owners of industrial companies is undoubtedly important. While large companies are more subject to structured operational processes that include evaluation of energy use and are characterised by higher operational capacity, managers and owners of SMEs tend to have more limited awareness and understanding of the benefits and opportunities associated with interactive and flexible energy systems. They may not be fully aware of the potential cost savings, energy efficiency improvements, or environmental benefits that can be achieved through participation. Limited access to information and specialized knowledge can hinder their ability to engage with these systems effectively [81].

More generally, energy efficiency and the related measures are often not fully understood and are frequently not seen as strategic decisions by companies; therefore, they seldom reach board decisions. Most energy audit reports remain at the technical level and seldom go to senior management for discussion. Direct links with the corporate investment cycle are rarely made and energy-efficiency investment decisions usually result from the implementation of energy management systems (e.g., ISO 50001) or the initiative of energy managers [82].

There tends to be a lack of awareness of energy management systems. This generally means there is a poor understanding of the energy demand dynamics within a given industrial facility. The level of awareness depends on energy prices, the energy intensity of the production processes and whether there is a technical/management team that specifically focuses on energy flows within corporate processes.

3.3 Legal barriers

If we look at the legal aspects of demand side flexibility in the EU, there are currently several barriers that are not favourable to customer engagement, most particularly for residential customers, who account for the majority of the theoretical demand response potential, but also for industrial customers. The main legal barriers can be related to market exclusion, contract issues, data privacy and access to information, and lack of standards and interoperability requirements. The following subsections aim to further explain and develop each of those barriers.

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3.3.1 Market exclusion

Existing regulatory and policy frameworks sometimes limit the ability of customers to participate in demand response (DR) programmes and offer flexibility to the system. Independent aggregators are essential to engage residential customers in flexibility markets since they help to aggregate flexibility resources and DR capabilities of multiple customers into a unified and marketable product [83]. However, the regulatory framework on independent aggregators is not harmonised within the EU [84]. Apart from this, in some countries the legal framework to enable aggregation of flexible demand and other DERs can be missing or underdeveloped, making it difficult for smaller customers to participate in flexibility markets.

On the other hand, the deployment of new technologies is, in some cases, hindered by complex regulations and procedures, which can make it difficult for customers to access and use such technologies. There are several DR technologies available to be used by prosumers, such as vehicle-to-grid solutions that allow electric vehicles (EVs) to inject power into the grid when not in use, which are not widely spread due to insufficient incentives (limited access to finance and public budget) and low/slow returns on investment [85].

Moreover, engaging customers in flexibility at an energy community level might be very efficient in shaving the peak demand on the distribution grid. Nonetheless, there is a lack of regulatory framework to ensure sufficient financial gains to invest in technologies that would make this feasible [86].

While active DSOs engaging in smart system integration is a prerequisite for enabling active customers, the existence of a regulatory framework supportive of such developments is an important factor to highlight, and currently, it tends favour grid investment over demand response. However, from a regulatory perspective, these two options for grid development need to be equally competitive [87]. Thus, there must be benefits for DSOs when choosing a DR-based solution for a local energy system challenge that traditionally could have been solved with more grid reinforcement.

Another aspect that might limit the access to the market by flexibility service providers is the lack of regulation to avoid the bundling of DSOs and suppliers (i.e., utilities), acting jointly to attract customers. This may make the flexibility market less competitive and, consequently, with less attractive offers for customers to engage [86]. In particular, it is important to guarantee equal treatment among FSPs. As there is a considerable variety of FSP characteristics and also DSO needs, it is essential to be technology-neutral when setting up the specifications, with the aim of ensuring a level playing field [88].

A regulatory framework that enables the utilization of online peer-to-peer platforms, and consequently the purchase or sale of power produced by the assets of energy customers (e.g., rooftop PVs) without an intermediary is also missing [85][85]. In order to be effectively implemented, peer-to-peer and virtual power plant models require the producers and customers to be allowed to participate in aggregations and the roles of potential stakeholders must be clearly defined by the legal framework.

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3.3.2 Contract issues

Flexibility contracts normally show a lack of flexibility for the customers to switch or terminate them whenever they wish and, apart from that, customers still struggle to understand their energy contracts [85]. This relates to the fact that contractual conditions and related information are not always provided in an accessible and clear way to customers and, even though obligations exist in the European legal framework, problems can still emerge at the transposition level. For instance, customers sometimes lack clear information regarding the origin of the energy they consume. Although the market for guarantees of origin (GOs) exists in all EU Member States, as it was established as an obligation of the first Renewable Energy Directive, several national regulatory authorities (NRAs) reported that, in general, for the year 2020, they do not verify whether energy volumes sold with GOs associated to them are being backed by corresponding volumes of purchased GOs. Thus, as of 2020, for those NRAs who are not competent authorities for disclosure and/or issuing bodies of GOs, it is not possible to provide energy disclosure statistics on the origin of the energy consumed, such as the specific energy sources that customers chose each year with the corresponding volumes consumed [89].

Another barrier to customer engagement can be found in the private rented sector, given that across most of Europe, if tenants wish to install a heat pump or PV panels, without the cooperation of their landlord, they have very limited options. This comes from the "split incentive" issue of the private rented sector: tenants do not have the rights to implement long-term changes to the property and, additionally, it would not be very appealing for them to invest in a property owned by someone else. The landlord, on the other hand, has little incentive to invest in switching to renewables or improving the property's energy performance, considering that the energy bills are paid by the tenant. However, participation in flexibility markets without such investment may be difficult or impossible altogether. Legal obligations for landlords to improve the energy rating shall be further elaborated. Some EU Member States, such as Germany, France and Belgium, are already running some pilot projects on this regard [90].

3.3.3 Data privacy and access to information

Sophisticated technologies, such as smart meters and other energy monitoring systems, are essential for the implementation of DR programmes. However, there is a lack of regulation to ensure customers are fully aware of and consent with the energy data they share with their energy service providers. At least four privacy-related issues emerge from the current access to customers energy data: 1) inference of sensitive information, since individual appliances may be identified; 2) discriminatory customer segmentation, for example if high peak time users are suddenly offered less favourable tariffs; 3) in a cohabitated house, the energy bill payer may claim ownership of consumption data, even without other cohabitants' consent; and 4) data can be aggregated in a non-controlled way, by machine learning algorithms, given that the most powerful insights may result from linking with additional data sources, such as loyalty cards, social media or data from other smart devices [91].

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Legislation is needed to prevent customers to have their data sold by the energy service provider for marketing purposes without consent. This is what the General Data Protection Regulation (GDPR) does. However, some deficiencies may remain. For instance, an important issue related to energy consumption data is the non-limited range of time for which data can be kept by its owners. This might be an issue, given that "the longer the data is kept, the greater the chance of misuse, either accidentally or maliciously" [91]. In addition, as the innovative electrical appliances that allow customers to take part in DR programmes rely on connected devices and technologies, customers might inherently be more vulnerable to cyberattacks [85].

Also, for the reasons explained above, the potential for unauthorized access to the data collected by smart meters represents a significant concern for customers. There is a common understanding among European DSOs and TSOs that having access to sub-meter data by the customers can provide more accurate measurements of short activations, an essential input to facilitate baseline calculation and verify delivery from specific assets. Therefore, it is suggested that network codes shall be adapted to cover sub-meter data requirements and include rights for SOs to access such data. SmartEn agrees that although sub-metering can provide many benefits and advance innovation and local energy trading and sharing, the use of sub-meter data shall be on a voluntary basis and upon customer's consent [92].[92]

In that sense, data integration issues related to the compliance with the General Data Protection Regulation (GDPR) are a crucial condition for an acceptable roll out of DR contracts that are highly based on customer data collection [86]. Nonetheless, it has been discussed that the GDPR is still missing the regulation of data collection, as opposed to data use. Energy service providers have the possibility to anticipate this regulation evolution, by adopting best practices and collecting only the data that is necessary to provide good services. Regulation shall ensure that energy service providers would collect and share as little information as necessary, leaving additional information sharing as an option for the consumer to decide, in order to enable customers to choose their privacy over other benefits, if desired [91].

Moreover, the complexity of the regulatory framework surrounding data protection and privacy among Member States can make it difficult for service providers to navigate and comply with all the applicable laws and regulations [93].

3.3.4 Lack of standards and interoperability

Currently, there is a lack of standardization and existing guidelines, which makes flexibility an unfamiliar and abstract concept. This barrier becomes prevalent when it comes to implementation, considering that for a pilot project to be scaled up it must be applicable for all properties even if those are spread out geographically. Due to different DSOs, this may consist of a barrier, since the same market may not exist in all regions which raises up the urge for collaboration and standardization of solutions [94].

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Standardisation and interoperability are crucial because of rapid technological evolution. For any customer device connected to a digital network, embedded interoperability is essential [85]. In that sense, the European Commission has highlighted the importance of establishing interoperability requirements and foresees several initiatives with that purpose, including the adoption of an implementing act on interoperability requirements for access to metering and consumption data[15]. Apart from that, the Commission will also promote a code of conduct for energy-smart appliances to enable interoperability and enhance their participation in DR schemes [95][95][96]. Nonetheless, there is still a lack of minimum EU requirements to support interoperability as well as missing regulations for preventing or discouraging vendor lock-in [83]. For example, if a customer's smart thermostat is not compatible with his or her utility's DR programme, the customer may not be able to participate [83].

Additionally, the relationship between DSOs and customers in the energy landscape of the (near) future needs to be digital and highly automated. Anything less will result in a poor customer experience and cause frictions in the electricity market. To combat this, policy and regulation need to be enacted that will enable DSOs to open active and easy dialogue with their customers [85].

It is also important to know what the limits of technology standardisation are. If a standard generates a “one size fits all” way of doing “something” when many innovative and competing ways exist to do that “something”, then standards can limit innovation, which is not beneficial. A standard should be, instead, a common “platform” on top of which market operators can innovate. Furthermore, implementing standards is challenging, given that the energy industry is undergoing rapid technological advancements and experiencing shifting regulatory landscapes. Therefore, standards need to evolve to keep pace with these changes. The introduction of new or updated standards can create complexities, as organizations must continually adapt their practices and technologies to meet the latest requirements. This dynamic environment can lead to uncertainties and additional costs for industry participants [97].

Box 3.7 - Questionnaires results on legal barriers.

This box provides insights on legal barriers to customer engagement based on the results of two different interaction moments organised in the framework of T11.6.

According to the first questionnaire, for most of the OneNet cluster demonstrators, regulation or a specific piece of legislation represented a significant barrier to customer engagement. More specifically, the respondents to the first questionnaire mentioned the following main legal barriers: minimum bid

[15] On 6 June 2023, the European Commission adopted the Implementing Regulation on ’Interoperability requirements and non-discriminatory and transparent procedures for access to metering and consumption data’. For more information, see: https://energy.ec.europa.eu/news/commission-adopts-new-implementing-act-improve-access-metering-and-consumption-data-2023-06-06_en

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requirements, lack of specific legislation and/or incentives, rules on public procurement and prequalification process, and the GDPR. Some cluster demonstrators overcame these barriers with specific agreements with the customers involved in the OneNet project.

According to aggregators and customers who answered the second questionnaire, no relevant legal barriers have been faced during the engagement process. Actually, this can be explained by considering the special conditions which circumscribe OneNet cluster demonstrators. For instance, the absence of a real market in the Spanish and Cypriot demonstrators made legal constraints on data protection not relevant for the demonstrators.

Box 3.8 - Legal barriers to engage energy communities.

This box provides insights into the legal barriers that are connected to the engagement of energy communities in flexibility markets.

Although both the RED II and the IEMD require EU Member States to ensure the rights of RECs and CECs to access all suitable markets without discrimination compared to other market actors, a clause which would also apply to flexibility markets, there are still barriers connected to the lack of national regulations and often the mismatch between national and European regulations [6][7].

In more detail, article 22(2)(c) of the REDII and Article 16(3)(a) of the IEMD require Member States to ensure that energy communities can access markets not just individually but also through an aggregator. This implies that market design rules need to allow energy communities to access different markets through a third party. This differentiation is important, because most energy communities will experience significant difficulties gaining direct access to the market, either due to the complexity of the market or the technical nature of the community's projects. Therefore, when designing their wholesale and balancing markets, Member States still need to ensure that rules provide equal access to ensure aggregators of smaller generation units and consumption loads can participate [98].

According to an ACER and CEER report, in 11 Member States and Norway, prosumers more generally are allowed by the national legislation to provide flexibility services. However, prosumers through aggregators have very limited or no access to the electricity balancing markets. This occurs due to the criteria for entering the market, e.g., high-capacity thresholds, resulting in flexibility and demand response services permitted to be mostly offered by industry or large generators [17].

Furthermore, something to be considered is that a frequency services provider (BSP) requires significant loads and are very demanding, while congestion management and local flexibility markets are not in place yet in most EU Member States. Therefore, it can be considered that markets are not yet mature. Flexibility for energy sharing optimisation could be an emerging market, but rules are slowly being put in place and will

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require efforts from all stakeholders to be successful (communities, DSOs and technology service providers). Also, there is a lack of legislation in some cases which would promote infrastructure development, such as smart meters and infrastructure for data management, which slows down the engagement of energy communities with flexibility and increases cost.

In addition, there are legal barriers energy communities are facing due to the incomplete transposition of the EU regulatory framework for RECs and CECs. Although the transposition deadline for the RED II and the IEMD has already passed, several Member States have still not included provisions for energy communities in their national legislation or did so only partly. Due to that, local actors cannot set up energy communities or face several regulatory and administrative barriers in the process of developing community energy projects. Additionally, in some contexts there is a reluctance among government actors to make deep changes in energy systems that were designed for centralised electricity supply, resulting in regulations that make it challenging for new actors to establish decentralised energy systems [79].[16]

Finally, the lack of stability in national legislation and the mismatch that is often observed between national and European regulations can also be considered as a barrier for the participation of energy communities in flexibility markets. Uneven development of the market for demand response across Europe and incomplete frameworks for aggregation still hamper the development of demand-side services [99].

Box 3.9 - Legal barriers to engagement of industrial customers.

This box aims to analyse the main legal barriers that hinder the engagement of industrial customers in flexibility markets.

The existing regulatory framework may not be designed to accommodate the participation of industrial customers in demand response or flexible energy systems. Regulations and policies may primarily focus on larger energy customers or utility-scale operations. This makes it challenging for smaller companies to navigate and comply with the legal requirements. The lack of specific provisions or incentives for smaller companies can act as a legal barrier to their participation.

In practice, SMEs often have different contractual arrangements with energy suppliers or utilities compared to larger industrial customers. These contracts may not include provisions for demand response participation or flexibility in energy usage. Renegotiating contracts or obtaining necessary approvals from energy providers and suppliers can be legally complex and time-consuming for SMEs.

[16] The transposition progress of the definitions, enabling frameworks and support scheme provisions for energy communities at all Member States is depicted in the REScoop.eu transposition tracker, which highlights legal barriers identified in the national legislations.

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Participating in demand response or flexible energy systems may require access to market mechanisms or platforms where energy services are traded or coordinated in a sophisticated manner. Industrial customers may face barriers in accessing these markets due to membership requirements, financial obligations, or eligibility criteria. Limited market access can hinder their ability to participate and benefit from the economic opportunities associated with flexible energy systems.

Implementing demand response and participating in flexible energy systems often involve sharing energy consumption data and operational information. Industrial companies need to comply with data privacy regulations and ensure the security of sensitive information. Meeting legal requirements related to data protection, privacy, and cybersecurity can be a challenge, especially for SMEs with limited expertise or resource [51].

3.4 Technical barriers

From a technical point of view, when one speaks of demand side flexibility, the first thing that comes to mind is that there is a need for innovation to achieve it. This technical need has two intertwined parts. On the one hand, there is the need to invest in the infrastructure; on the other hand, however, there must be a potential to justify the investment in enabling or improving the infrastructure. This causes the deployment of such hardware to take place at different rates from region to region [60]. Interaction with the network must take into account the type of considered customers as well, and for this reason a consumer-centric approach was considered for this study. Within this framework, our research question concerns the technical prerequisites for the participation of these customers in flexibility markets. In other words, what are the requirements and circumstances that can enable or hinder customers to provide flexibility services?

In this analysis, three big groups of barriers were identified based on the literature and revisiting the information of WP4, more specifically those included in deliverable 4.3.[17] One of these barriers is about the information and communication technology (ICT) infrastructure and the way in which power systems are constructed, meaning their architecture; then, as the second group comes the data and interfaces that need to be used for data exchange; and, finally, the design and communication of the platforms that will interact with the different customers. The description of these groups of barriers is provided in the next subsections.

3.4.1 Lack of infrastructure and harmonised architecture

[17] The deliverable 'Guidelines for TSO-DSO-consumer system integration plan' is available at: https://onenet-project.eu/wp-content/uploads/2022/12/OneNet_D4.3_v1.0.pdf.

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This group of barriers relate to the technical limitations of the existing infrastructure that supports the flexibility markets and the architecture upon which these are built.

Depending on the infrastructure and on the technical capabilities, the customer can participate in different kinds of contracts (see Section 3.3.2). One of these contracts is the control-based contract in which the customer cedes control over specific appliances to the counterparty in the contract. Therefore, the customer is not expected to react to any signals herself or himself in this case. There are challenges in selecting the best suitable contract, and from the technical perspective understanding how to use the functionalities of the appliances comes into the big picture. In this regard, customers need to have energy-efficient appliances and equipment that can be easily programmed and controlled to reduce energy consumption during peak demand periods.

In this context, the lack of smart meters, possibly due to resistance to their roll-out, and the technical problems that some smart meters experience, such as failing GPRS data connections, can also create technical barriers to customer engagement since it is expected that these devices will enhance the rewards from active market participation [23]. It is also essential to have an energy monitoring system in place, in order to separate the energy flows and select the proper charges/appliances that participate in the provision of flexibility.

Flexibility service providers (FSPs) may find it challenging to interact with certain systems due to their complexity. The closed nature of some IT environments and solutions can also make it difficult for FSPs to connect and exchange data with other systems. In addition, not all customers can join all solutions meaning that there need to be a good study of the requirements of these customers and the classification of the different types when providing solutions; otherwise, a lack of inclusivity in the market may follow. Furthermore, data exchange is traditionally one-way, meaning that it goes from customers to DSOs, and is mainly used for billing purposes only. This one-way data flow can limit the potential for prosumer activity via P2P trading and other innovative business models that can be leveraged by exchanging the data also from the SO to the customers, like for example the importance of showing to customers their real-time consumption and letting them decide how to utilize their loads and generations. Finally, Quality of Service (QoS) should also be guaranteed to ensure that customers receive a reliable and consistent service [100].

3.4.2 Data exchange

This group of barriers relates to the challenges associated with data exchange and communication protocols. One significant challenge is the lack of consent mechanisms for third-party data sharing, which can limit the ability of FSPs to access customer data. Additionally, missing standards and data models to enable communication can make it difficult for different systems to communicate effectively. Indeed, there is usually a diverse range of data models and ontologies, including tailor-made, vendor-specific, and not open-source solutions, that can make integration more difficult. Another point is interfaces, which are not unified and can limit the potential for effective data exchange. Finally, as the number of smart appliances and devices connected

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to the grid increases, the volume of data generated and exchanged by customers, generators, and distribution systems will grow significantly and will be considerably higher than it currently is. When this data goes upstream to the aggregators and other market operators, it will be necessary to handle and interpretate large amounts of data, so investment not only in infrastructure but also in knowledge on big data management will be required, which can be a barrier for most FSPs.

3.4.3 Interface design and communication

This group of barriers relates to the design and communication challenges associated with energy flexibility markets. One challenge is the lack of a single point of contact and better coordination, which means there is a lack of uniform solutions between energy suppliers and DSOs. This can create confusion for customers and limit the potential for effective data exchange. The usability and cost of some energy management systems can also create barriers to customer engagement. Additionally, custom web-based models for each vendor/aggregator can create challenges when interacting with customers. Finally, connectivity between energy suppliers and customers can be constantly sustained through channels such as email, social media, web platforms, mobile phone applications, and smart home management systems. User experience and usability are the main topics to enable good interaction with customers. In this context, customer engagement is clearly related to the engagement of users with demand response products and services, with good to great usability and user experiences [43].

It is often not easy for customers to see these technical problems at an early stage because the reasons for participation in markets and the behavioural aspects attract most of the attention. Nevertheless, over time there will be more experience and quantitative analysis of the benefits of the participation for small customers that will foster a broader participation; in turn, such a broader participation is likely to reveal the technical problems that can hinder the possibility for small customers to participate in these markets.

Box 3.10 - Questionnaire results on technical barriers.

This box provides insights on technical barriers to customer engagement based on the results of the second questionnaire submitted to cluster demonstrators in the framework of T11.6.

According to the aggregators who answered to the questionnaire, technology represented a relevant barrier to customer engagement because of system complexity and the need of smart meters equipped with software that allows dynamic steering. The necessary metering and communication infrastructure to monitor and control flexibility resources were only partially present. For most aggregators, the technical solutions were interoperable and allowed remote control. In the Cypriot demonstrator, in particular, the implementation of smart meters was an important issue, as well as interoperability with customers and between different suppliers when designing solutions. Even though technical barriers have been overcome

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within the demonstrator, future issues can emerge in terms of scalability: experts form the Cypriot demonstrator agreed that when the number of users and connected devices will be high, it will be necessary to invest in infrastructure and training for the management and analysis of big data.

According to end customers who answered to the questionnaire, the decision to join the OneNet project was not followed by any problem on the technical side. Interfaces have been evaluated as user-friendly by 50% of the respondents.

Box 3.11 - Technical barriers to engagement of energy communities.

This box highlights the technical barriers to engage energy communities in flexibility markets.

Firstly, there are barriers connected to the lack of infrastructure. The lack of smart meters or their slow deployment has been evident around the EU and, consequently, several community energy practitioners have faced issues with the involvement in flexibility services. Smart meter deployment is a crucial part in many cases of the implementation of local community-based schemes (e.g., self-consumption, flexibility services, energy efficiency). In some EU Member States, the cost to obtain smart meters on a voluntary basis is higher than when such meters are deployed in a centralised manner. This fact prevents energy communities from obtaining this necessary tool [101]. Moreover, there are some barriers connected to data management, as often data from DSOs is shared too late to be useful for the provision of flexibility services. Furthermore, the lack of transparency and information sharing from public administrators or the system operator can constitute a challenge for energy communities to engage in flexibility services [102].

In addition, a certification framework that examines whether energy market solutions follow established open standards or not and are able to interoperate or not is missing. While manufacturers should remain free to create their own walled-garden solutions, what constitutes a barrier is the lack of enforcement of the device manufacturers to fully respect a common interoperable standard, alongside their proprietary solutions, which would be a significant step onwards to allow brand-agnostic flexibility services [99].

In line with the above, the absence of a common communication standard makes the integration of devices from different manufacturers (e.g., a heat pump and a water boiler) in a single flexibility offer very difficult. What is lacking is the availability of a “plug-and-play” configuration for all user’s devices, which would greatly widen the range of possible end-users [99].

With regards to the management of the infrastructure, some barriers are connected to the lack of information, technical expertise and lack of skills for setting up energy communities and engaging in flexibility. Grid maps are also not always accessible and readable by citizens. When the distribution grid has to be taken into account (e.g., when setting-up an energy sharing scheme), the lack of tools that support easy access to network data by citizens and communities can represent a barrier to their engagement. What also may

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constitute a barrier is that grid planning may not involve municipalities, while it also does not provide opportunities for DSOs to spare grid capacity for planned community energy projects [102].

Box 3.12 - Technical barriers to engagement of industrial customers.

This box highlights the technical barriers to engage industrial customers in flexibility markets.

Advancements in technology – together with targeted policies and regulatory measures – have allowed the development of robust and adaptable energy systems that can integrate well with complex processes in large, energy-intensive industries, ensuring compatibility and minimising disruptions to operations. However, technical barriers hindering the engagement in flexibility markets are more visible with regard to smaller companies. Various reasons justify this situation.

SMEs, especially those operating with limited resources, may have legacy control systems that are outdated or manual and thatlimit SMEs' ability to participate in flexible energy systems [81].

Integrating into flexible energy systems often requires compatibility and interoperability with different technologies, protocols, and communication systems. SMEs may face challenges in aligning their existing equipment, devices, and infrastructure with the technical requirements of a flexible energy system. Ensuring seamless integration and data exchange between the SME's systems and the broader energy system can be a significant technical barrier.

Effective participation in flexible energy systems requires the ability to collect, analyse, and communicate data related to energy consumption, load profiles, and demand response actions. SMEs may lack the necessary data management infrastructure and capabilities to handle the volume and complexity of energy data. This includes challenges in data collection, storage, processing, and communication, as well as ensuring data privacy and security.

SMEs may have limited knowledge and expertise in interfacing their operations with the broader energy system. This includes understanding and integrating with demand response platforms, energy management systems, and grid management protocols. Lack of familiarity with the technical aspects of the energy system and the associated interfaces can pose obstacles for SMEs looking to participate in flexible energy systems [36].

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4 Recommendations to address barriers to customer engagement

This chapter aims to provide potential recommendations to overcome the barriers to customer engagement that have been identified in Chapter 3. In our analysis we identified at least one recommendation for each type of barrier. Moreover, in order to convey our analysis more clearly, the main recipients of each recommendation were indicated. These are: governments, regulators, municipalities, educational institutes, system and market operators, FSPs and research institutes, The relevance of these recipients is identified on the basis of who we expect to implement the recommendations to promote customer engagement. We also provided, when relevant, specific recommendations for energy communities and industrial customers.

4.1 Recommendations for economic barriers

To overcome the economic barriers with regard to customer engagement defined in Section 3.1, it is important to provide the necessary economic incentives for customers to engage, to ensure this engagement is economically viable, and to have in place a market structure that is conducive to the participation by customers.

Table 4.1 presents the main recommendations identified to address the economic barriers to customer engagement in flexibility markets. These main recommendations follow directly from the analysis of the barriers presented in Chapter 3 and can be split up into more detailed recommendations.

Table 4.1 - List of recommendations to address economic barriers to customer engagement.

Recommendations	Economic barriers	Recommendation recipients
Increase the value of flexibility through value stacking, cost-reducing and interoperable devices, allowing free choice of FSP and energy supplier, and implementing a conducive tariff designs	Limited value of flexibility	Regulators, system operators, market operators
Improve data and information availability through digital meters, forecasting tools, and improve data sharing through data frameworks and platforms or flexibility resources registers	Risk and uncertainty, current market and product design	System operators, market operators, FSPs, research institutes

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Ensure the inclusion of economically vulnerable groups	Risk and uncertainty	Regulators
Increase R&D to conduct advanced profiling of customers, to better assess the (economic) benefits of providing flexibility versus its drawbacks, and to increase knowledge on baseline methodologies	Risk and uncertainty, current market and product design	Research institutes, FSPs, system operators, market operators
Increase focus on customer and aggregator business models and related information sharing	Current market and product design	Regulators, system operators
Make registration processes and market platforms more uniform	Current market and product design	Market operators

4.1.1 Increase value of flexibility

Although the current value of flexibility is not so high, it has been increasing, and, hence, also its business case is becoming more interesting. Therefore, we can assume some barriers are already slowly being removed. Efforts here should thus be focused on letting the intrinsic value of flexibility emerge entirely and allowing customers to fully exploit it. There are a number of ways in which this could be done. First of all, value stacking should be supported, for instance by removing certain stipulations in contracts and market rules that specifically do not allow for participating in different markets at the same time with the same underlying resources. Then, investment or market entry costs could be reduced by providing support for certain devices (by means of subsidies for instance), or by stimulating the market for certain devices such as smart meters, home energy management systems, etc. An important remark here is that it is very important to ensure the interoperability of such devices. This can be done by promoting the use of standards, open application programming interfaces (APIs) and Open Data [25]. Additionally, there should be a free choice of the FSP and the energy supplier (i.e., these roles do not necessarily have to be executed by the same actor) for all customers willing to participate in flexibility markets as this can increase market flexibility and the attractiveness of demand response in some markets [36]. Finally, as certain grid tariff designs may lead to higher costs for providing flexibility, attention should be paid to implementing tariff designs that are supportive for the engagement of flexible resources. This entails, for instance, that these tariffs should be easy to understand, have supporting tools/devices readily

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available and do not create conflicting signals to the customers by being complementary to market-based flexibility and commodity pricing.

4.1.2 Reduce economic risk and uncertainty

A number of recommendations can be made to reduce the economic risk and uncertainty associated with the participation in flexibility markets. First of all, there is a need for increased information availability. This entails the availability of accurate measurement data and feedback towards the end customer (as already mentioned in Section 4.1.1), the availability of self-explanatory and easy-to-use feedback tools (see Section 4.1.1), and clear communication of (economic) benefits to the end customer [25]. Moreover, advanced profiling could provide customers with better information, tailored to their individual needs, facilitating superior decisions with regard to investments in energy-related assets and acceptance of commercial energy offers [25]. Linked to this, adapted tariff schemes and necessary consumer tools for market participation are needed to ensure the inclusion of economically vulnerable groups [25]. Moreover, more R&D is needed to be able to better assess the (economic) benefits of providing flexibility compared to the associated drawbacks. And, finally, further discussions are needed between the regulators and involved market parties to keep reducing risks and removing uncertainties.

4.1.3 Develop a suitable market and product design

To increase customer engagement in flexibility markets, when designing markets and products, there should be an increased focus on the customer and on aggregator's business models and related information sharing. By reducing administrative and transaction costs which derive from participation in flexibility markets, net financial benefits can increase. Here, again, easy access to information and communication on all the processes surrounding it is important. Linked to this, more uniform registration processes and market platforms are desirable. For instance, with regard to data availability, the availability of digital meter data and improved forecasting tools is crucial. Additionally, data sharing can be improved through data frameworks and platforms or flexibility resources registers for the registration of flexibility assets. Regarding baselining, more research on baseline methodologies specifically for customers is needed as best practices are currently not available. Finally, when it comes to product design, clear product definitions are needed, considering technology-neutrality, and product standardization and harmonization should take place at an appropriate level.

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Box 4.1 - Industrial customers: recommendations to address economic barriers.

This box provides possible recommendations to overcome economic barriers that hinder the engagement of industrial customers in flexibility markets.

With industrial companies being profit-oriented entities, any engagement strategy should reflect the company-specific business case. It should also be kept in mind that investments to enable participation in flexibility markets must be economically attractive in comparison with the other investment opportunities available to each company [9].

Cost-benefit analysis and accounting practices can be improved to support demand response and flexible energy solutions in large companies, both energy intensive and not, by considering not only immediate financial returns but also the long-term benefits, such as improved energy efficiency, reduced operational costs, potential revenue from demand response programmes, and enhanced reputation due to sustainability efforts. Additionally, accurate data collection and analysis can provide more precise estimations of potential savings and incentives.

Specifically on the smaller companies, in order to overcome barriers associated with capital investments and legacy infrastructure, financial incentives and support for infrastructure upgrades could be provided. Financial incentives, grants, or access to financing options can help address resource constraints. Tailored solutions that minimize operational disruptions and provide risk management strategies can also encourage SMEs' participation in flexible energy systems.

Moreover, several market operators can support SMEs and contribute to reduce the economic costs associated with participation in flexibility markets: energy service companies (ESCOs), aggregators and energy utilities. In this regard, a main recommendation to overcome economic barriers could be to foster the role of these actors in the customer engagement process.

Energy service companies are specialised in providing energy-related services, including demand response, to support SMEs. They can assess SMEs' energy consumption patterns and develop customised demand response plans. ESCOs integrate demand response capabilities into SMEs' energy management systems, optimizing energy usage during critical periods. They analyse performance, provide feedback for improvement, and conduct financial analyses to assess cost-effectiveness. ESCOs enable SMEs to contribute to grid reliability, reduce energy costs, and respond to market signals. Their expertise in energy management and demand response empowers SMEs to participate effectively and realize the economic benefits of demand response programmes.

Demand response aggregators play a crucial role in unlocking the demand response potential of SMEs and non-energy-intensive businesses. By combining the energy reduction and load shifting capabilities of these

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participants, aggregators can offer a more significant and reliable demand response resource to grid operators and utilities. Aggregation increases the value and effectiveness of demand response, allowing smaller customers to collectively contribute to grid stability and reliability. Additionally, aggregators help these businesses access financial incentives and negotiate favourable contracts, providing a compelling motivation for their active engagement in demand response activities, while ensuring fair compensation for their contributions.

Energy utilities have already proven to be instrumental in developing and implementing demand response (DR) programmes customized for SMEs and non-energy-intensive industries. Utilities play a vital role in managing the day-to-day operations of DR programmes, including the enrolment and registration of participating businesses, monitoring, and verifying load reductions, and ensuring smooth programme implementation. They continuously evaluate programme performance, gathering feedback from SMEs and non-energy-intensive industries to identify areas for improvement. Utilities design attractive incentive structures and benefits to encourage engagement in DR activities, such as financial incentives like reduced electricity rates, capacity payments, or direct payments for load reduction. Additionally, they may offer non-financial benefits such as priority access to energy efficiency programmes, enhanced customer support, or public recognition for participating businesses. By providing these tailored DR programmes and incentives, utilities empower SMEs and non-energy-intensive sectors to actively contribute to grid stability and reap the rewards of their participation.

4.2 Recommendations for behavioural barriers

Recommendations presented in this section are a response to the main behavioural barriers identified in Section 3.2. They represent possible strategies to overcome these kinds of barriers and thus promote customer engagement in flexibility markets. Broadly speaking, the main goal of the recommendations to address behavioural barriers is to change the way customers perceive energy and adapt consumption and investment patterns to provide flexibility to the system. As analysed in Task 3.3 of the OneNet project, in a consumer-centric market, energy is no longer perceived as a commodity but as a service whose economic value can reflect the preferences of a specific customer.

Moreover, as an overarching principle, we should always keep the customer perspective in mind: in this regard, whenever interacting with a customer, we should guarantee that each effort he or she exerts is worthwhile. In other words, each recommendation should be implemented preserving a positive balance between the expected benefits (or gains) and the expected concerns (or costs) of a customer (or a group of customers).

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Four main recommendations to address behavioural barriers have been identified and are discussed in the following sub-sections:

1. Know your customer(s),
2. Promote educational campaigns on flexibility markets,
3. Use effective and clear communication,
4. Implement measures to overcome the status-quo bias.

Table 4.2 List of recommendations to address behavioural barriers to customer engagement.

Recommendations	**Behavioural barriers**	**Recommendation recipients**
Know your customer(s)	All	All
Promote awareness campaigns on flexibility markets	Lack of awareness	Governments, regulators, municipalities, educational institutes and market operators
Use effective and clear communication	Lack of skills to elaborate information	Mostly market operators
Implement measures to overcome the status-quo bias	Status-quo bias	Regulators and market operators

4.2.1 Know your customer(s)

As described in Section 2.1.1, different groups of customers can be identified according to common socio-economic characteristics. In order to implement effective engagement strategies, the first step is to identify the strategy's target group. In fact, no engagement strategy can be successful if it does not take into account customers' characteristics. Engagement strategies should reflect:

1. customers' socio-economic characteristics,
2. customers' behavioural characteristics (see Section 3.2).

The aforementioned characteristics can also change over the life of a customer, which means getting to know the customer is an ongoing process that does not end, for example, with the signing of a contract. Collecting customer information is an expensive task that can, however, be facilitated by, for example, the increasing availability of data on consumption characteristics. In fact, digital technologies can enable the detection of customer values and preferences that cannot be recorded without them. This can lead to satisfying customer

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preferences better, but it can also lead to demand discrimination that could reduce customer surplus.[18] Therefore, regulation is important to ensure competition in these segments [103][104].

All the recommendations that follow should be tailored to the specific type of customer under consideration. Therefore, the importance of knowing customers applies to all public and private entities that will be mentioned below as recipients of the specific recommendations. For example, regulators should also deepen their expertise in behavioural economics, since the economic theory behind regulation often does not take these aspects fully into account.

4.2.2 Promoting awareness campaigns on flexibility markets

An awareness campaign is an initiative that aims to educate customers on the existence of a problem, a new economic opportunity and/or a product.[19] As described in Section 3.2.1, to date customers have a low awareness of energy-related topics. Awareness campaigns can promote the establishment of a favourable background in which customers are more receptive to these topics, thus facilitating the customer engagement process.

Social and psychological factors shape the customers' awareness of the energy field. For example, habits are influenced by the context in which a customer lives and they limit the basket of opportunities the customer is aware of. Moreover, different groups of customers have different objectives when it comes to energy use and different degrees of knowledge of the energy sector. In particular, knowledge of flexibility markets is mostly limited to professionals and a few customers already well informed about energy topics. This implies that awareness campaigns should take this high variability among different customer groups into account and should be implemented based on specific objectives and target groups. For highly informed customers, the awareness campaign can directly focus on disseminating specific information on flexibility markets. On the contrary, for non-informed customers the approach should be more gradual and based on a perspective that considers what is sensible for the target group. For example, residential customers may be informed about the possibility of pursuing economic savings related to energy consumption without needing to have a clear understanding of how flexibility markets work.

In light of this, awareness campaigns' impact can be twofold:

1. changing the social context where the customer lives,

[18] Demand discrimination means that not all customers pay the same price for the same good or service, as the producer(s) is(are) able to discriminate them on the basis of their maximum willingness to pay.

[19] According to Kotler et al. (2005), a product is 'anything that is offered to a market for attention, acquisition, use or consumption and that can satisfy a want or need.' Even when a product is a physical object what is being sold is a service, such as the ability to enable participation in a market [2].

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2. changing the customer mind-set.

In fact, people do not change on their own only but also on the basis of their peers: a positive interaction with an acquaintance can offer a stimulus where an awareness campaign has failed. Moreover, different awareness campaigns may reflect different customer sensitivities. In this regard, a mix of different messages is highly recommended. Some messages may focus on economic aspects, some on environmental issues, and some on technological innovation: this increases the spectrum of drivers influenced by awareness campaigns.

Awareness campaigns can take place in different contexts and, therefore, should be carried out by different actors. Advertisement campaigns are a viable solution in terms of available alternatives: they can be promoted on mass media by new market operators, energy companies and public institutions. They can aim at different goals: promoting new services, new business models, new sensitivities and preferences. Other kinds of awareness campaigns can be promoted in contexts of social interaction, including through the contribution of organizations that have been successful in gaining customers' trust (see Section 4.2.4). For example, a local initiative or a project that aims to engage the local community can be promoted by workshops organised by the municipality, local university, etc. Awareness campaigns can be targeted for "the next generation" of customers: consider, for example, initiatives that can be organized for high-school students.

It is sensible to expect that the effects of awareness campaigns require time to materialise. Moreover, considering the economic resources that are needed to implement these campaigns, a collaboration between the public and private sectors may be necessary. The public sector (i.e., the government or other public authorities) should be geared toward awareness campaigns that aim at a general redefinition of the cultural paradigm of our society in the medium and long term. The private sector, on the other hand, is usually interested in collecting results over a much shorter time horizon. Therefore, market operators should be able to attract the interest of customers, at least those who have already shown a general inclination to get engaged in energy topics. Obviously, this can be done only if an economic interest in engaging new customers exists.

4.2.3 Use effective and clear communication about flexibility-related offers

Customers need to understand potential benefits and losses when evaluating participation in flexibility markets and acceptance of specific offers by market operators. At the same time, messages should be clear and simple to prevent customers from feeling overwhelmed by the amount of information and to avoid burn-out effects [105]. How to manage this trade-off between transparency and simplicity of information depends on the type of customer in question, particularly 1) their ability to process information and 2) the goals they want to pursue. Producing customised messages for each customer would be too expensive. However, different kinds of customer groups can be identified (see Section 4.2.1) and this can offer a reasonable compromise between implementation costs and customisation requirements. In fact, as seen in Section 2.1.1, it is possible to identify common needs or preferences for customers belonging to the same classification group.

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Moreover, messages should not create false expectations in terms of benefits that then risk not materializing. In light of this, in order to make offers clearer and more comparable, information messages should focus not on the technical nitty-gritty or on details of how flexibility markets work but rather on a few key parameters of the service(s) that are offered to the customer and the related benefits (and costs). This strategy is consistent with the changing customers' perception of energy from a commodity to a service, on which different preferences can be expressed.

Messages should also be effective over time. To ensure that:

1. messages should be provided when their expected impact is larger: changes in customers' lives (e.g., relocating to a new house, buying a new car) represent a window of opportunity to make behavioural changes easier to implement [105][106]. In fact, these represent moments where it is easier to change long-standing habits and people are more receptive to change. Moreover, a change in lifestyle makes it more likely that new habits will be adopted: broadly speaking, it is easier to adopt new behaviours than changing the existing ones;
2. messages should be provided also after a successful engagement process: in order to promote customer retention, customers need to know their actions make sense and have produced concrete results. This feedback can be personalised according to customer preferences (e.g., kg of CO_2 saved per month, € saved per month, kWh from renewable sources used, etc.);
3. messages should change during the lifetime of a customer: lifestyles and priorities change over time, as does sensitivity to different kinds of information.

Feedback is a particular kind of information that can be determinant to establish a successful engagement strategy [107][107]. People need to know their actions are leading to results. Feedback should be provided using the most appropriate channel: mails, smartphone apps, smart-home devices or a mix of these (this may change depending on the type of customer addressed and her access to digital technologies – see Section 3.2.2) [108]. Moreover, tips and advice can be used to set new "goals", such as to increase energy saving over time. Feedback can also provide information on energy prices in order to steer demand.

Regardless of the particular type of information and channel being used, customers need to feel part of a process: in order to facilitate a change in energy-related behaviour, people "need a meaning" and not to feel patronised.

Considering the specificity of the messages analysed above, the main recipients of these recommendations are market operators.

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4.2.4 Implement measures to overcome the status-quo bias

Not all customer behaviours can be changed. As analysed in Section 3.2, customers are not perfectly rational and "inefficiencies" in decision-making are inevitable. Although not all elements that contribute to characterise the status-quo bias can be corrected, some measures can be introduced to reduce their impact. In particular, in the following we propose measures to reduce the negative impact of inertia and lack of trust in the customer engagement process.

Customer inertia depends on many variables. If a precise cause of inertia can be identified, then it can be acted upon but, unfortunately, this is often not the case. One possible solution is to use customer inertia itself to foster the engagement process.

Opt-in mechanisms could overcomplicate participation in flexibility markets. Therefore, participation could be offered as a standard (default) solution. Default participation can obviously present some side effects and raise concerns regarding the necessary protection for certain categories of customers. For this reason, minimum customer protection measures should be implemented and, more in general, customers should be allowed to decide whether to participate in such markets and, hence, opt-out options should be always available. In order to create an incentive to remain engaged in flexibility markets and address the status quo bias, these solutions should only be available through an effort on the part of the customer (e.g. by filling out a specific request). In this regard, policymakers and regulators should act quite carefully.

Trust is a pillar of every economic and social interaction. Energy can be seen as a production input or as an input to benefit from a service and, thus, it is extremely relevant in terms of safeguarding economic activities or quality of life. When considering changes in consumption patterns, customers need to be reassured that their needs are safeguarded and that they will not face unexpected extra-costs [108]. This means, for example, that for some of them comfort cannot be compromised by market participation or by the adoption of a "non-conventional" technology; for others, data cannot be utilised without their consent.

Trust can be strengthened by acting on several levels. As highlighted in Section 3.2.3, people do not trust energy companies much. In this regard, a change in the current perception requires time to become effective but the first move is up to market operators. If new and old market operators can offer successful solutions, more and more people will be willing to participate in flexibility markets. Being successful is not only about providing services and technologies that satisfy customers but also about paying attention to responding promptly to customer problems and establishing transparent communication with them. These actions could also have positive spin-offs due to social networks: mistrust can be mitigated by sharing positive experiences among peers.

In this regard, (regulatory and technical) measures that increase network and customer observability can raise trust because they may reduce errors (e.g., in energy bills) by market operators and reduce switching times.

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Moreover, a public registry of "certified" intermediaries could be put in place to provide further guarantees to customers that they will be treated fairly and with competence by the actors listed in the registry. These registers could be managed by an independent body, such as a regulatory authority, and could provide a comparative advantage in terms of trust over market operators that do not fulfil the requirements for being included. Lastly, contracts should take into consideration customers' needs and safeguard them. In this regard, contracts for participation in flexibility markets could be concluded in such a way that only certain precise types of devices would be managed by a third party or guaranteeing minimum comfort levels in all circumstances.

Box 4.2 - Industrial customers: recommendations to address behavioural barriers.

This box provides recommendations in order to overcome behavioural barriers that hinder the engagement of industrial customers in flexibility markets [109].

As pointed out in Section 4.2.2, awareness campaigns, educational programmes, and capacity building initiatives can enhance the understanding of demand response and flexible energy systems among industrial customers.

Business associations and chambers of commerce can play a vital role in promoting awareness and overcoming hesitations among SMEs regarding demand response opportunities. They can achieve this by providing educational resources, organising workshops and networking events, sharing best practices and success stories, advocating for favourable policies, collaborating with energy service providers, facilitating pilot programmes, and recognising companies that have implemented demand response effectively. Business associations and chambers of commerce can empower small industrial customers to understand the benefits of demand response and encourage implementation [105].

On a technical support level, several market operators can play an active role in these kinds of initiatives, such as aggregators and utilities. They raise awareness about the value of demand response participation, the potential cost savings, and the associated environmental benefits. By providing educational materials, webinars, and training sessions, aggregators could help businesses understand how demand response can align with their sustainability goals and contribute to a more resilient energy system. Moreover, they can provide clear and accessible information on programme details, participation requirements, potential cost savings, and the positive environmental impact [110].

4.3 Recommendations for legal barriers

Recommendations presented in this section are a response to the main legal barriers identified in Section 3.3. Possible strategies to overcome those barriers are discussed, aiming at promoting customer engagement in flexibility markets. The main goal of these recommendations is to identify and propose improvements to the regulatory framework around flexibility markets, concerning customer participation in DR programmes.

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Five main recommendations to address legal barriers have been identified:

1. Improve the regulatory framework to make flexibility markets more inclusive,
2. Establish fair, robust and switchable energy contracts,
3. Promote best practices in privacy protection of customers,
4. Minimize ambiguities in the law and industry standards,
5. Promote digitalization of system operators.

Table 4.3 - List of recommendations to address legal barriers to customer engagement.

Recommendations	**Legal barriers**	**Recommendation recipients**
Improve the regulatory framework to make flexibility markets more inclusive	Market exclusion Contract issues	Regulators, DSOs, governments
Establish fair, robust and switchable energy contracts	Market exclusion Contract issues	Regulators, contractors, governments
Promote best practices in privacy protection of customers	Data privacy and access to information	Contractors, regulators, governments, key stakeholders
Minimize ambiguities in the law and industry standards	Lack of standards and interoperability	Regulators
Promote digitalization of the electricity system	All	Regulators

4.3.1 Improve the regulatory framework to make flexibility markets more inclusive

The regulatory framework shall facilitate the entry of independent aggregators into the market and their engagement with customers. In addition, electricity suppliers should not obstruct customers to engage with independent aggregators, and aggregators should not be given the power to undermine customers' rights to switch suppliers or choose a specific tariff. When promoting market inclusion for all customers, regulation must also ensure protection of the participants, therefore, mitigating actions shall be implemented to protect customers from excessively high wholesale electricity prices during exceptionally volatile periods [89]. Moreover, policies shall support the inclusion of vulnerable low-income households, by providing clear, simple and proportionate regulatory frameworks.

In fact, the recently proposed Reform of the EU electricity market design introduces such measures to protect customers from the volatility of electricity prices, providing them with better contract choices and access

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to low carbon energy. Apart from that, it also proposes measures for customers to being able to share renewable energy directly, without needing to create energy communities [111].

Whereas TSOs have a reasonable visibility of the flexibility needs on their grids, DSOs still lack it, which may hinder the participation from LV customers in flexibility markets. This visibility is dependent on several factors, such as smart meters' roll out. The revised Renewable Energy Directive, currently in negotiation, establishes that TSOs and DSOs provide information to third parties on the share of RES and the GHG emissions associated with the electricity supplied in each bidding zone. Such data should be readable via electronic communication devices (e.g., smart meters and sub-meters, EV charging stations) [111][112].

These types of proposed measures would enable electricity market participants to help end-users optimizing their energy consumption in reaction to external signals and be able to offer their flexibility in various markets. To effectively engage customers, information shall be as accurate and as close to real time as possible [106][107].

Experts involved in the webinar on 9 May[20] considered it crucial for the regulatory framework to improve the electricity market's scheme, by applying more dynamic prices and network tariffs. Customers shall be clearly given the possibility to participate in flexibility markets, supported by regulation to provide them with benefits from being active customers. Moreover, regulation shall ensure that the new DR schemes always provide the option to opt-out, meaning that the customer can terminate the contract easily. It is also crucial to develop and implement robust price comparison tools, reflecting the cost of network tariffs, so that customers can know exactly their potential gains and can protect themselves against bill shocks. These DR schemes shall work in such a way that, for instance, a customer would be rewarded if he or she contributed to solving a congestion in the distribution grid (or helped in preventing its occurring).

In that sense, customers who opt for dynamic prices for electricity should be allowed to pay bills by instalments whenever the amount to be paid exceeds the average charged in the past. As of response to the unprecedent energy crisis faced in 2022, ACER identified a total of 400 emergency measures adopted by governments to protect customers against the high prices of electricity and gas [113]. Some of the identified measures might be applied to flexibility markets, aiming at protecting customers and making them feel safe to engage in DR programmes. The European Commission electricity market reform proposal forces suppliers to offer customers the options to have a dynamic or fixed price contract and Member States need to verify if suppliers have appropriate hedging strategies not to go bankrupt during a possible crisis, when customers count on the protection they have paid for. Member States shall also appoint a supplier of last resort responsible to supply the electricity to customers to whom the original supplier has ceased to operate. The European Commission electricity market reform proposal encourages prosumers to share energy amongst themselves and

[20] The experts involved were: Sonja Klingert, Senior Researcher at Universität Stuttgart, Jörg Mühlenhoff, Senior Energy Policy Officer at BEUC, and David Batič, Head of Development & Market Monitoring Department at Slovenian Energy Agency.

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strengthens the benefits of making Power Purchases Agreements (PPAs) more widely available to customers, with measures such as state guarantees to cover financial risks [113]. These measures can protect customers who signed contracts with dynamic prices from being exposed to very high electricity prices.

The need for a framework of incentives for distribution companies was identified by the involved experts, such as unbundling the DSO from suppliers to promote flexibility offers. In a similar way, the regulatory framework should be developed in a way that is conducive to the use of flexibility as an alternative option to conventional investments, in cases flexibility is seen as more efficient and effective.

4.3.2 Establish fair, robust and switchable energy contracts

To encourage customers to engage in DR programmes, it is very important to allow them to easily terminate and/or switch contract. In that sense, regulation on limiting termination fees might be essential. For a fixed-term contract, early termination fees should be correlated to a benefit provided to the customer (e.g., a discount or a price promotion on energy). Energy suppliers should be required to provide evidence of the true cost of charging termination fees in such circumstances. The cost must be fair and appropriate, given the benefit provided to the customer. Contracts should offer transparency concerning the duration of the contract and termination, so that in case of tactical renewal, the customer is able to finish the contract with a month's notice and free of charge [43].

It is expected that the rise in dynamic price contracts and the introduction of new products will attract additional suppliers, increasing market competitiveness. This rise in competitiveness, trust and innovative new items may cause customers to switch more frequently [43]. Complementarily, with the aim to protect vulnerable customers, regulatory authorities shall supervise the market to avoid unfair clauses for tariff changes and ensure that offers are understandable, transparent and comparable. Moreover, it is important to ban clauses with a disproportionate or uncertain termination fee, that may discourage customers to change contracts [42].

Providing customers with a contract with GO may increase their interest in hourly price contracts and the advantages on moving their consumption away from peak hours. It may also serve as an incentive for customers to become prosumers or, for instance, acquire an electric car. In that sense, contracts with renewable energy GO are important in many levels for environmentally-conscious customers [89].

Blockchain technology may allow the development of smart contracts that make it possible to share automatic control within networks in a replicable, secure, verifiable and trustworthy manner [114]. Smart contracts could be used to share control of energy units for prosumers and optimization of energy usage, while providing opportunities for trading excess energy. Putting laws such as no. 4513/2018 (from Greece) into practice might expand the concept of virtual net metering, which allows for collective energy sharing within a community [115]. Portugal has also implemented energy sharing mechanisms, through DL 15/2022, and has

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developed a pilot to test new forms of energy sharing, allowing hierarchical and dynamic approaches for the local production to be split among collective self-consumers [116]. Moreover, applying automatic generation control is essential to overcome short-term supply-demand imbalances. It is also important to enable changing demand in response to remote SO control. This shall be done in contracts with large and small customers, by applying automated load control by the SO or to grant the SO direct load control of energy-intensive devices, like water pumps, refrigerator units and air conditioners [117].

The "split incentive" issue, described in Section 3.3.2, that usually occurs in the private rented sector between the landlord and the tenant, can be minimized by applying regulation that encourages the landlord to equip the rented property with energy efficient or renewable-based solutions. For instance, some federal states in Germany have implemented a "solar obligation" for several buildings and rooftops, which should only be taken into consideration if the proper regulatory frameworks and incentives are in place to ensure that additional costs do not fall on tenants and that tenants' rights are safeguarded in the process [90].

4.3.3 Promote best practices in privacy protection of customers

As mentioned in Section 3.3.3, data privacy and access to information might hinder costumers from engaging in DR programmes. One of the most important steps to overcome this issue is to ensure full compliance with GDPR, by being clear about the type of customers data that is collected, who can access it, for which purpose data is used, how it is protected and the period of time during which it is stored and where. Flexibility services shall follow the principle of "privacy by design" and ensure that no more data than necessary is collected and that it is not kept for longer than needed. Customers should also be able to request access to their data, have it corrected or deleted, and give consent before it is used for marketing purposes, even if doing so would be justified by a legitimate interest under GDPR. To ensure that the customer can get a good overview of how their data will be used and be able to assess this before signing any contract, the privacy information for each contract shall be readily accessible and gathered in one single place, instead of being scattered across privacy policies, terms and conditions desired [91].

Meanwhile, because more advanced DR programmes rely on connected devices and technologies, such as smart meters and mobile apps, customers can become more vulnerable to potential cyberattacks. Governments, working with key stakeholders, shall ensure that the entire energy value chain is cyber resilient, by adopting proper legislative frameworks, developing and sharing best practices, or obtaining international certification.

The EU's 2019 electricity market directive for example, requires third parties to proceed with the "installation, operation, data handling and maintenance" of metering devices to comply with EU data protection and privacy rules. Governments can promote a wider embrace of digital business models, including DR programmes, by conveying these regulations—along with the advantages and hazards connected with digitalization—through public awareness campaigns (see Section 4.2.2) [7].

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4.3.4 Minimize ambiguities in the law and industry standards

Eliminating ambiguities in the law and industry standards might also help pave the way for new business models that leverage on customer engagement in flexibility markets. One example involves licensing electric vehicle charging operators. If all the European countries adopt similar regulation in what regards the licensing rights and safety standards for using electric vehicles, such technology would very likely be more widely spread. Energy communities involved in energy sharing and the provision of flexibility also need a method to handle potential charge imbalances, clear rules and procedures to govern their interactions with utilities and retail customers.

Standardization and interoperability are crucial since technology advances so quickly. Embedded interoperability should be the foundation for any customer device connected to a digital network. In that sense, regulators and standard-setting organizations need to be proactive in engaging with industry stakeholders to capture emerging technologies while maintaining necessary safeguards.

Recent developments by the Energy Networks Association (ENA), from the UK, have reduced the procedure for coupling intelligent heat pumps and cars to power networks. Standards that are widely adopted set performance criteria for companies and lower the entry barriers for producers and service providers. Another example of standardization in energy systems is the “Digitalizing the Energy System - EU Action Plan”, officially adopted by the European Commission, which builds on the requirements from the Renewable Energy Directive and aims to establish a common European energy data able to support innovative energy services, in which demand-side flexibility (DSF) should be included [96][118]. The Action Plan also supports the development of smart grid indicators to monitor smart and digital investment in the grid, with the aim to not only enhance the efficiency of the grid, but of the energy system as a whole [96]. This initiative might harmonise the information customers should have access to, in order to actively and wisely take part in flexibility markets.

Since DR programmes typically evolve by interconnecting components from different sectors (from the most varied electrical appliances to smart meters), strengthening the cooperation among regulators and other relevant authorities to work more efficiently across sectors is of a very significant importance. This requires better coordination and information sharing among relevant authorities especially where cross-cutting issues occur.

It is essential to standardize some key elements, such as smart meters, by supporting their deployment to increase the visibility of DSOs and understand the circumstances where it would be preferable to provide an automatic or manual response to the customers on their DR programmes. For the one hand, smart meters are one of the most important factors to ensure the success of DR programmes and, on the other hand, without the right regulatory support, they may put customers’ privacy at risk. Therefore, it is crucial to establish clear pre-

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qualification and validation protocols concerning smart meters, apart from all the other points already mentioned [112].

Lastly, the new Implementing act recently adopted by the Commission foresees the implementation of interoperability requirements and non-discriminatory, transparent procedures for data access on metering, consumption, as well as data required for customer switching, demand response and other services, potentially related to DSF [119]. By being applied, this act might facilitate the full interoperability of energy services within the EU in order to promote competition and avoid excessive administrative costs [120].

4.3.5 Promote digitalization of the electricity system

Promoting the digitalization of the electricity system will support customers to engage in DSF programmes in several different ways, from online platforms to compare electricity prices to increased DSO visibility and deployment of peer-to-peer online platforms to allow prosumers to exchange energy.

There are diverse regulatory actions that can promote the digitalization among the different stakeholders of flexibility markets, namely:

1. Performance-based regulation – to incentivize SOs to invest in digital solutions. Regulation can define performance metrics related to system reliability, grid performance, efficiency gains, and customer service. Operators that demonstrate improved performance through digitalization can be rewarded through financial incentives, such as bonus payments or performance-based tariffs [121].
2. Cost recovery mechanisms – digital investments can require significant upfront costs. Regulation should include mechanisms that allow SOs to recover these costs over time. This can be achieved through cost-tracking mechanisms, such as specific allowances, which are included in the regulated tariffs. Providing a transparent and predictable path for cost recovery can encourage operators to invest in digital solutions [122].
3. Data access and interoperability – regulations should address data access and interoperability requirements to enable seamless integration of digital solutions. They can outline data sharing obligations, data protection measures, and standards for data exchange. Ensuring open and secure access to data can facilitate collaboration among stakeholders and enable the development of innovative digital services and applications [123].
4. Regulatory sandboxes and pilot projects – allow DSOs and TSOs to test and deploy digital solutions in a controlled environment, namely for DSF. These initiatives provide operators with flexibility and regulatory oversight, allowing them to experiment new technologies and approaches. Regulatory sandboxes can help identify barriers and enable the refinement of regulation based on real-world experiences [124].

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Box 4.3 Energy communities: recommendations to address legal barriers

This box provides recommendations in order to overcome legal barriers that hinder the engagement of energy communities in flexibility markets.

To start with, in order for energy communities to be able to participate in the market without discrimination, EU Member States should ensure a full transposition of the provisions for energy communities laid down in European legislation [125]. This includes not only the transposition of the definitions, rights and duties of RECs and CECs, but particularly the creation of an enabling framework for them and the proper consideration of RECs in the development of support schemes. Governments should also implement Article 22(3) of the RED II which obliges Member States to carry out an assessment of barriers and potentials for the development of RECs. They should use the information gained from this assessment to establish meaningful enabling frameworks for RECs that will remove the barriers for RECs to participate in energy markets, including those for flexibility.

It should be highlighted that the creation of an effective enabling framework for energy communities can be regarded as a multi-level governance task. Therefore, it requires commitment and actions of policy makers at all levels of government (national, regional and local), including simplification and streamlining of administrative procedures such as permitting, grid connections, and so on, without compromising environmental protection and biodiversity goals.

In line with this, as highlighted in the barriers section above, legal instability and constant changes in energy community legislation prevent citizens from participating in energy communities; therefore, a stable and complete national enabling framework for RECs and CECs is expected to incentivise their engagement in different activities, including flexibility provision. This enabling framework should be combined with legislation promoting infrastructure development, including smart meter deployment and provisions that ensure transparency with regards to data management.

Moreover, national governments should also create a legal framework for collective energy consumption schemes and energy sharing. They should enable and incentivise the implementation of these activities and remove administrative barriers. Incentives for energy sharing may include reduced grid charges or special premia for the energy shared among community members, provided they do not undermine cost-reflectivity of grid tariffs.

In more detail, energy communities are facing barriers to the use of local sites for production or the access to the grid because of their small size and limited resources. The ongoing discussion about a reform of the EU electricity market design provides an important opportunity to assess and possibly improve the existing rules that ensure the possibility for active customers and energy communities to access the electricity grid and

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participate in energy markets on an equal footing. In this context, it would be important to evaluate the possibility to modify the existing rules to ensure energy communities enjoy:

- priority in the use of public spaces that are made available for installation of renewable energy production;
- priority when it comes to obtaining a grid connection and gaining access to the grid; and
- technical assistance and streamlined procedures for energy sharing projects.[21]

As a concluding remark it should be highlighted that, when designing their wholesale and balancing markets, EU Member States should ensure that the rules put in place provide equal access to aggregators of smaller generation units and consumption loads [98].

Box 4.4 Industrial customers: recommendations to address legal barriers

This box provides recommendations in order to overcome legal barriers that hinder the engagement of industrial customer in flexibility market.

Addressing legal barriers for industrial customers requires a comprehensive approach involving policymakers, regulatory bodies, and energy market stakeholders. This includes developing regulations and policies that explicitly consider the needs and participation of companies (in particulars SMEs), streamlining approval processes, and providing guidance on contract renegotiation. Collaboration between legal experts, industry associations, and energy providers can help overcome legal barriers and create a more inclusive and supportive environment for SMEs in flexible energy systems.

Energy Service Companies (ESCOs), aggregators and energy utilities can play a relevant role in order to overcome legal barriers. Overall, ESCOs, demand response aggregators, and energy utilities play interconnected roles in supporting SMEs in their participation in demand response programmes. Their collaborative efforts aim to simplify the adoption of flexible energy systems, advocate for favourable policies, provide necessary resources, and optimize programme effectiveness, ultimately enabling SMEs to contribute to grid stability, reduce energy costs, and optimize their energy usage [10]. ESCOs can play a crucial role in supporting SMEs throughout the process of enrolling in demand response programmes. They can assist SMEs in navigating the enrolment process, ensuring that they meet eligibility criteria, and understand contractual obligations and incentives associated with the programme. ESCOs can provide guidance and expertise to help SMEs optimize their participation in demand response initiatives.

Demand response aggregators can simplify the participation process for SMEs and non-energy-intensive sectors. They act as intermediaries between individual businesses and demand response programmes,

[21] An assessment of the proposal by the European Commission focusing on energy communities can be found in [126].

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handling enrolment, registration, and contractual obligations on behalf of multiple participants. This alleviates the administrative burden for SMEs, allowing them to focus on their core operations while still benefiting from demand response opportunities. By streamlining the process, demand response aggregators enable a broader range of SMEs to engage in demand response activities [110].

Energy utilities play a critical role in supporting SMEs and non-energy-intensive sectors in demand response programmes. They provide access to energy consumption data, empowering businesses to monitor and analyse their usage patterns. Utilities may also offer tools and platforms that allow SMEs to visualize and manage their energy consumption effectively. By facilitating data access and management, utilities enable SMEs to make informed decisions and optimize their participation in demand response programmes. Furthermore, utilities continuously evaluate the performance of demand response programmes targeting SMEs. They analyse participation rates, load reduction results, and customer feedback to identify areas for improvement. Based on these evaluations, utilities refine programme designs, adjust incentive structures, and implement enhancements to maximize programme effectiveness and benefits for SMEs.

4.4 Recommendations for technical barriers

As stated in Section 3.4, customer engagement in flexibility markets can face three groups of technical barriers: lack of infrastructure and harmonised architecture, data exchange, and interface design and communication.

Five main recommendations to address these technical barriers have been identified. They are presented in Table 4.4 and follow directly the assessment of barriers provided in the previous chapter.

Table 4.4 – List of recommendations to address technical barriers.

Recommendations	Technical barriers	Recommendation recipients
Anticipate the infrastructure needs and design solutions for each type of user	Lack of infrastructure and harmonised architecture	Government, regulators, and market operators
Unify data models and protocols using standards	Data exchange	Government, regulators, educational institutes and involve experts in each domain
Provide user-friendly interfaces with clear navigations and communications	Interface design and communication	System operators and market operators

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Support third-party technical enablers and support (i.e., ESCOs, technical aggregators)	Information provision and implementation	SMEs and industrial actors

4.4.1 Anticipate the infrastructure needs and design solutions for each type of user

To overcome the group of architectural and infrastructure barriers, smart meters need to be prepared and used to enable remote measurement and monitoring of energy use. This allows energy providers to identify and manage real-time fluctuations in demand and supply. These devices contain firmware, a type of software that provides low-level control over the device's hardware functionality and communications. It is crucial for this firmware to possess reliable and robust functionalities that can be easily updated whenever necessary. Moreover, preparing strategies for these devices to face cybersecurity threats and personal information leakage, from an early stage, is critical [1]. Once these devices are installed, a two-way communication needs to be enabled so that data can be sent from the SO to customers and not only the other way. For the platforms that will be designed, these points should be taken into account, but not only that, there also need to be designed solutions for different perspectives, meaning that the requirements need to be designed for different groups of customers, and not give a solution just by thinking of customers as a whole, that is where the segmentation and differentiation of customers is important. Regarding Quality of Service (QoS), the infrastructure should be designed with reliability, robustness, scalability, and cost-effectiveness in order to detect failures and quickly respond to disturbances [127].

4.4.2 Unify data models and protocols using standards

In addition to the architecture of platforms and the infrastructure, the information layer should be considered, which corresponds to the second group of barriers identified above and related to data and interfaces. The barriers in this layer are needed to be solved to provide the data exchange in a good manner, so for this, the development of transparent and easily understandable consent mechanisms for data sharing should be prioritized. The development and adoption of unified interfaces and industry-wide standards for communication protocols and data models can promote greater compatibility and interoperability between different systems. And finally, governments and industry stakeholders should invest in training and capacity building to support the handling of large amounts of data [128].

4.4.3 Provide user-friendly interfaces with clear navigations and communications

Once these data integrations are implemented and real-time data on energy usage, prices, and market conditions are shared, customers can leverage this information and make informed decisions about their energy use and participation in flexibility markets. Energy providers will be able to provide this information through

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smart meters, mobile applications, or other platforms. Regarding these platforms, to encourage customers to participate in flexibility markets, it is important to provide user-friendly and accessible platforms that allow them to monitor and control their energy use [43]. These platforms should have user interfaces that are intuitive and easy to navigate. It is important that when providing more than one platform, all the platforms follow the same design and provide a similar user experience, like for example the items in the menu, the use of labels and concepts, and also the navigation. In addition, good communication, education, and support can be given to customers by exploiting the best guidelines for usability. Finally, energy providers or aggregators can offer training, workshops, and other resources to help customers understand the status of their participation in flexibility markets and how to improve it, explaining the mechanisms that are used and the way in which their assets and data are treated.

Another important enabler of customer participation is automation, which can help to simplify participation in flexibility markets for customers. Building automation systems (BAS), energy management systems (EMS), and other automated technologies can be used to adjust energy use automatically in response to market signals or other events. Customers need to have these capabilities in their facilities, and in cases where these already exist, modifications should be contemplated based on the operational requirements of the DR programme [129].

Open source is also a good way to promote greater integration and compatibility between different systems and provide end-to-end transparent operations that can be checked and audited by anyone and also maintained (i.e., extend, correct, and perfect the different platforms) by the open-source community.

Box 4.5 – Industrial customers: recommendations to address technical barriers.

This box provides recommendations in order to overcome technical barriers that hinder the engagement of industrial customers in flexibility market.

Overcoming technical barriers requires support and resources for SMEs. This includes providing technical guidance, offering training and capacity building programmes, promoting standardized communication protocols, and facilitating the adoption of automation and control systems. Collaboration between energy providers, technology vendors, and industry associations can help address technical challenges and enable SMEs to effectively implement demand response and become part of flexible energy systems. Providing guidance, training, or outsourcing options for technical expertise can assist SMEs in navigating the technical aspects of flexibility markets participation.

Energy Service Companies (ESCOs), demand response aggregators, and energy utilities can provide the necessary technologies, operational support, and guidance to help businesses curtail energy usage and contribute to optimise their energy utilisation.

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ESCOs can help SMEs deploy the necessary technologies and infrastructure, such as smart meters and energy monitoring systems, to participate in demand response programmes. ESCOs also offer operational support during demand response events, helping SMEs curtail or shift their energy consumption and ensuring compliance with programme commitments.

Demand response aggregators provide technology and controls to enable demand response participation for SMEs and non-energy-intensive sectors. They deploy advanced energy management systems and offer operational support, assisting businesses in implementing demand response strategies and monitoring their performance.

Energy utilities can assist companies in overcoming technical barriers related to demand response. They can provide technical guidance, conduct energy audits, and offer assessments to identify areas for improvement. Utilities can help with technology implementation, including smart meters and energy management systems. They can also provide training and education on demand response protocols and data management. By granting access to real-time energy data and analytics, utilities enable informed decision-making. In addition, utilities can offer technical support to address any issues during demand response implementation. Through these efforts, utilities play a crucial role in helping companies navigate technical challenges and successfully participate in demand response programmes. Finally, energy utilities can coordinate with grid operators to integrate demand response resources effectively and ensure grid reliability.

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5 Conclusions

The power sector is undergoing a transformative change with the increasing recognition of the value of flexibility. In this deliverable, we delve into barriers to customer engagement in flexibility markets and provide recommendations to overcome them. By removing barriers, stakeholders can unlock the untapped potential of flexibility and create an environment that fosters active customer participation, leading to a more flexible and customer-centric power system.

Our work was mostly based on an extensive literature review on the topic of customer engagement in areas such as the adoption of environmentally friendly behaviour, switching energy tariffs, participating in energy conservation programmes, and engaging in demand response programmes. One of the main results of our work was the identification of four groups of barriers to customer engagement in flexibility markets: economic, behavioural, legal and technical barriers. Our recommendations to customer engagement reflect these four groups of barriers.

Economic barriers and related recommendations

Economic barriers can be divided into three categories: limited value of flexibility, risk and uncertainty, and current market and product design. The limited value of flexibility is attributed to factors such as the absence of economically viable business models for different customer segments, high upfront investments with uncertain returns, and the limited potential for value stacking across markets. Risk and uncertainty arise from a lack of clarity about the business case for offering flexibility, difficulty in assessing benefits and impacts, and unclear allocation of costs and incentives. Current market and product design present challenges through high administrative and transaction costs, complexity that excludes economically vulnerable groups, inconsistent registration processes, absence of appropriate baseline methodologies for low-voltage customers, and product design attributes that may hinder customer participation.

Leveraging the value of flexibility can be achieved through various measures, including supporting value stacking, removing certain stipulations in contracts, reducing investment and market entry costs, and promoting interoperability of devices through standards and open data. Providing customers with the freedom to choose their flexibility service provider and energy supplier, as well as implementing tariff designs that support flexibility engagement, are also important. Increasing information availability is crucial to reduce economic risk and uncertainty. This involves providing accurate measurement data, self-explanatory feedback tools, and clear communication of the benefits of flexibility to customers. Advanced profiling of customers and targeted information campaigns for economically vulnerable groups can help tailor engagement strategies and ensure inclusivity. Conducting more research on the economic benefits of flexibility will further strengthen the business case and encourage participation. Engaging customers in flexibility markets requires a focus on their specific

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needs and business models. This entails reducing administrative and transaction costs, improving data availability, and establishing uniform registration processes. Clear product definitions, technology-neutrality, and standardisation are essential for effective product design, enabling customers to easily understand and engage with flexibility options. With particular reference to industrial customers, addressing high upfront investment costs, uncertainty regarding return on investment, and resource constraints is paramount.

Behavioural barriers and related recommendations

Behavioural barriers can be divided into three categories: lack of awareness, lack of skills to elaborate on information, and status-quo bias. Lack of awareness refers to customers' limited understanding of the benefits of participating in flexibility markets. Customers may not prioritise energy consumption and struggle to grasp how their daily habits affect energy usage. Insufficient information on electricity bills, prices, and costs further hinders their comprehension. Misconceptions and limited knowledge discourage them from seeking information and adopting energy-saving practices. Lack of skills to process information stems from the complex and unfamiliar nature of energy-related choices. Customers need cognitive tools to gather, analyse, and prioritise information effectively, enabling them to make informed decisions. Limited knowledge, research costs, and information overload make it challenging to evaluate options, leading to decreased market participation. Status-quo bias refers to customers' tendency to stick with current decisions and avoid change. Transaction costs, uncertainty, cognitive biases, and emotional attachment to existing choices contribute to this bias. Loss aversion, where customers weigh losses more than gains of the same size, and customer inertia, seen in the resistance to switching suppliers and deployment of more energy-efficient, but initially expensive solutions, are interconnected factors. Lack of trust in institutions or market operators intensifies the status-quo bias.

The implementation of effective engagement strategies in flexibility markets calls for an identification of the target group based on customers' socio-economic and behavioural characteristics. Engagement strategies should reflect these characteristics and consider that they can change over time, requiring an ongoing process of getting to know the customer. Collecting customer information can be facilitated by the increasing availability of data on consumption characteristics enabled by digital technologies. Awareness campaigns play a vital role in promoting customer engagement. They should consider the variability among different customer groups and be implemented based on specific objectives and target groups. Messages should focus on economic aspects, environmental issues, and technological innovation, offering a mix of different drivers of customer engagement. Collaboration between the public and private sectors is necessary due to the amount of resources required and the different time horizons for desired outcomes. Effective and clear communication about flexibility-related offers is essential. Messages should be simple, transparent, and tailored to different customer groups. They should focus on key parameters of the service and its benefits rather than technical details. Feedback is crucial to establish successful engagement strategies, providing personalized information on results and fostering a

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sense of participation and meaning for customers. Measures should be implemented to overcome status-quo bias and address customer inertia and lack of trust. Opt-out options should be available, allowing customers to decide their level of participation in flexibility markets. Minimum customer protection measures should be in place, and trust can be strengthened through transparent communication, prompt problem-solving, and establishing positive experiences through social networks. Contracts should consider customers' needs and safeguard their comfort levels.

Legal barriers and related recommendations

Legal barriers can be divided into four categories: market exclusion, contract issues, data privacy and access to information, and lack of standards and interoperability. Market exclusion stems from regulatory limitations on customer participation in demand response programmes, especially for residential customers. Complex regulations and limited incentives hinder the adoption of new technologies for demand response. The absence of a regulatory framework for energy communities and restrictions on peer-to-peer energy trading platforms further impede customer engagement. Contractual issues involve inflexible contracts and a lack of transparency in energy contracts. Data privacy concerns arise from the sharing of energy data without clear consent and the risk of unauthorised access and cyberattacks. The lack of standardisation and interoperability makes it challenging to implement flexibility solutions.

Promoting competition and customer choice by enabling the entry of independent aggregators and preventing electricity suppliers from hindering customer engagement are two measures to address some of the existing legal barriers. Measures to protect customers from high wholesale electricity prices during volatile periods through fair pricing mechanisms and anti-market manipulation measures are necessary. Fair, robust, and switchable energy contracts are important, allowing customers to easily terminate or switch contracts without excessive fees and providing transparency in contract duration and termination clauses. Privacy protection is crucial, requiring compliance with data protection regulations such as GDPR. Implementing "privacy by design" principles, minimizing the collection of personal data, and obtaining customer consent for data usage are recommended. Mitigating privacy risks associated with connected devices like smart meters is also important. Minimizing ambiguities in the law and industry standards is essential for enabling new business models in demand response programmes. Standardization and interoperability are key to integrating emerging technologies and ensuring seamless communication among stakeholders. Licensing electric vehicle charging operators and developing smart grid indicators can provide clarity and guidance to market participants, fostering innovative solutions. Digitalisation plays a pivotal role in supporting customer engagement. Regulatory actions, such as performance-based regulation and cost recovery mechanisms, incentivise system operators to adopt digital solutions. Data access and interoperability requirements enable data exchange between stakeholders.

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Blockchain technology and smart contracts may offer opportunities for energy sharing and optimization, leading to more efficient and transparent flexibility markets.

Technical barriers and related recommendations

Technical barriers can be divided into three categories: lack of infrastructure and harmonised architecture, data exchange, and interface design and communication. Infrastructure limitations and technical constraints pose challenges, affecting customer participation and contract selection. The absence of smart meters and deployment issues further hinder engagement. Complex interactions and closed IT environments create obstacles for data exchange. One-way data flows and the lack of standards limit innovative business models. Data exchange barriers include consent mechanisms and communication protocols, restricting access to customer data. The absence of standards and diverse data models complicate interoperability. Increasing data volumes require infrastructure and big data management investment. Interface design barriers involve coordination issues, usability problems, and custom web-based models. Ensuring effective connectivity through various channels and prioritising user experience are crucial.

To enable remote measurement and monitoring of energy use, smart meters should be equipped with robust functionalities that can be easily updated when needed. Two-way communication between the system operator and customers is crucial for data exchange. Infrastructure design should prioritize reliability, robustness, scalability, and cost-effectiveness to detect failures and respond quickly to disturbances. Transparent and easily understandable consent mechanisms for data sharing should be developed to address barriers in data exchange. Unified interfaces and industry-wide standards for communication protocols and data models enhance compatibility and interoperability between systems. Training and capacity building are needed to effectively handle large amounts of data. User-friendly and accessible platforms are vital for customer participation in flexibility markets. These platforms should enable easy monitoring and control of energy use. Consistency in design across platforms, including menu items, labels, concepts, and navigation, provides a seamless user experience. Guidelines for usability ensure good communication, education, and support. Energy providers and aggregators can offer training and resources to help customers understand their participation status and improve it. A broader use of automated solutions simplifies customer participation and is of paramount importance, especially for smaller customers. The reliance on open-source solutions should be promoted as it fosters integration, compatibility, transparency, and accountability through community involvement in maintaining and enhancing platforms.

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Limitations and research outlook

The recommendations provided are the results of a high-level assessment of the barriers to customer engagement in flexibility markets and do not take extensively into account the specificities that each individual market for system services may have. The analysis and the production of recommendations benefited from the experience from the OneNet demonstrators, but this benefit was limited to some extent by the low number of real customers involved in the demonstrators and by the fact that market functioning was often simulated.

Therefore, in the future, it would be useful to increase the collection of empirical evidence by involving more real actors in on-field projects and possibly focusing the analysis on a specific system service/flexibility market in order to provide more precise recommendations. A detailed cost-benefit analysis of the specific recommendations might also be desirable to come up with further guidance to decision-makers and stakeholders.

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7 Appendix

In this Chapter we describe the two questionnaires we submitted to the OneNet clusters' demonstrators.

7.1 First questionnaire

Our first questionnaire to cluster demonstrators has been submitted in the context of the WP11 Regulatory questionnaire to all OneNet cluster demonstrators. The questionnaire aimed to identify the most relevant regulatory framework applied in the OneNet demonstration countries. Within the questionnaire, two relevant questions for T11.6 have been proposed:

Questions	Options	Answer
What type of customer(s) did your demonstrator(s) try to involve? [multiple answers are possible]	Residential consumers (e.g., individual households)	*[Y/N]*
	Groups of residential consumers (e.g., multi-apartment blocks)	*[Y/N]*
	Small commercial customers (e.g., shops and restaurants)	*[Y/N]*
	Large commercial customers (e.g., hotels and office buildings)	*[Y/N]*
	Small industrial customers (e.g., light manufacturing)	*[Y/N]*
	Large industrial customers (e.g., big factories)	*[Y/N]*
	Energy intensive industrial customers (e.g., steel or paper-making plants)	*[Y/N]*
	Other (please, specify)	*[please answer]*

Question		Answer
Did a specific piece of legislation or regulation represent a significant barrier in the customer engagement[3] process? Yes/No		*[Y/N]*
If yes, which one?	Did you manage to overcome that barrier?	If yes, how did you do that?
[Barrier nº1]	*[Y/N]*	*[please explain]*
[Barrier nº2]	*[Y/N]*	*[please explain]*
[Barrier nº3]	*[Y/N]*	*[please explain]*
[Barrier nº4]	*[Y/N]*	*[please explain]*

The questionnaire has been integrated with bilateral meeting with cluster demonstrators where relevant.

7.2 Second questionnaire

Our second questionnaire aimed to explore barriers faced by OneNet aggregators and customers during the engagement process. We submitted a set of about 30 questions divided according the four identified groups of barriers to both groups of respondents in the respective national language. The two questionnaires consisted of both multiple-choice and open-ended questions, introduced to obtain more details and clarifications. The questionnaires were only sent to demonstrators that engaged customers. In the others, customers have been merely simulated or were absent. We successfully collected responses from four clusters: Cyprus, Finland, Poland, and Spain. More specifically, four aggregators and eight customers answered our questionnaires.

In the following, you can find some explicative examples of the proposed questions:

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- Did the final customers' behaviour represent one of the main challenges for the provision of flexibility services in the OneNet demonstrator (e.g., because customers were reluctant to be enrolled in the demonstrator)?
  a. Yes
  b. To a significant extent
  c. To a minor extent
  d. No

Please, justify your answer

- Do you think the economic rewards promised to the final customer(s) for participating in the OneNet demonstrator were sufficiently attractive to foster the engagement process?
  a. Yes
  b. To a significant extent
  c. To a minor extent
  d. No

Please, justify your answer

- Did you face any problem with technology after you decided to participate in the OneNet demonstrator?
  a. Yes
  b. To a significant extent
  c. To a limited extent
  d. No

Please, justify your answer

- Did you face any problem with (existing) contractual or other legal obligations when you decided to participate in the OneNet demonstrator (e.g., need to inform and/or get the agreement of your energy supplier)?
  a. Yes
  b. To a significant extent
  c. To a little extent
  d. No

Please, justify your answer

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