Guidelines for TSO-DSO-consumer system integration plan

D4.3

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About OneNet

OneNet 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.

The project OneNet (One Network for Europe) is funded through the EU's eighth Framework Programme Horizon 2020. It is titled "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)".

While the electrical grid is moving 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. For this reason, the two major associations of grid operators in Europe, ENTSO-E and EDSO, have activated their members to put together a unique consortium.

OneNet will see the participation of a consortium of over 70 partners. Key partners in the consortium include already mentioned ENTSO-E and EDSO, Elering, E-REDES, RWTH Aachen University, University of Comillas, VITO, European Dynamics, Ubitech, Engineering, and the EUI's Florence School of Regulation (Energy).

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 consumers;
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
BRM	Balance Responsible Party
BUC	Business Use Case
DCE	Data Communication Equipment
DSO	Distribution System Oeprator
DTE	Data Termination Equipment
FR	Flexibility Resources
FSP	Flexibility Service Provider
H2020	Horizon 2020
HEMS	Home Energy Management System
IEMD	Internal Electricity Market Directive
mFRR	Manual Frequency Restoration Reserve
MO	Market Operator
MP	Market Platform
RES	Renewable Energy Sources
RR	Restoration Reserve
SCADA	Supervisory Control And Data Acquisition
SCD	Shared Customer Database
SESP	Smart Energy Service Provider
SUC	System Use Case
TSO	Transmission System Operator
UC	Use Case
VPP	Virtual Power Plant
WP	Work Package

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Executive Summary

This paper is the outcome from the work of task 4.3 of WP4 of the project OneNet. It provides a customer-centric perspective for the data exchange and communication in the interaction between TSO, DSO, market and customer. The outcome serves as a basis for the definition of a TSO-DSO-customer integration plan to improve the interoperability and, therefore, increase the flexibility exploitation, support the integration of renewable and distributed energy sources and improve the grid reliability.

The document introduces the applied methodology based on the work of the BRIDGE initiative. First, the outcome of numerous previous H2020 projects were reviewed to filter the relevant projects, which included the customer and discussed communication and data exchange with the customer. Then, the relevant projects were reviewed according to a pre-defined scheme to outline the state of the art in terms of customer-related interfaces, protocols and standards and to identify gaps and barriers. In the second step, the methodology is applied to the OneNet use cases, and the results are presented in a corresponding form. Beside these main modules, the outcome of a forum with international experts is integrated, as well as a consolidated view of the commonly reviewed projects at TSO, DSO and customer level.

Based on the collected information, the authors derived requirement specifications and concrete measures from the identified communication-related gaps and formulated concrete guidelines for data exchange with the customer and TSO-DSO-customer interoperability.

1 Introduction

To guarantee a secure and affordable energy supply in the future power grids with a significant amount of renewable energy sources, distributed resources and fluctuating availability of flexibility, the establishment of active system management is a central requirement.

Therefore, the main objective of WP4 is to link market activities with grid operators to maximize the integration of flexibility service providers (FSPs). This matter is examined from the perspective of TSOs, DSOs and consumers with a clear focus on interoperability and will provide technical integration guidelines from these three perspectives.

This document is one of three deliverables with a focus on the perspective of each of the three actors. The work in task 4.1 focuses on the TSO perspective, task 4.2 presents the DSO side, and the current deliverable for task 4.3 discusses the consumer perspective. The document is organized into 5 chapters. Chapters 1 and 2 introduce the topic and the followed methodology and approach. Chapter 3 holds the state of the art with the UC analysis of relevant H2020 projects and the categorization of the findings in tables addressing several aspects of interfaces and data exchange from consumer perspective such as standards, data models and protocols, as well as the basis for the analysis of TSO-DSO-consumer interoperability and integration. Furthermore, the chapter holds the work done to set the basis for the investigation of TSO-DSO-consumer interoperability, the GRIFOn forum and the consolidation of UC analysis done from the different perspectives. Similarly, Chapter 4 follows the same idea and presents the UC analysis of the OneNet demo UC for the Northern, Southern, Eastern and Western demonstration clusters. Chapter 5 presents the gap analysis for all reviewed UC and formulates guidelines and recommendations for TSO-DSO-consumer interoperability and consumer integration.

1.1 WP4 objectives

The main objective of WP4 is to define the interfaces in terms of information models, timing requirements and interaction sequences in the context of pre-qualification, schedules, maintenance etc., whilst covering mainly the operational challenges that arise from the introduction of new products and markets as analyzed in WP2 and WP3. Furthermore, recommendations for the development within OneNet are formulated based on a review of previous works, interaction with the OneNet demonstrators and close collaboration with the other OneNet WPs.

Finally, the work of the work package (WP) will be completed by an analysis of cybersecurity measures focused on the device level as a part of the proposed integration plan. This aspect is essential for the establishment of an integrated active energy system. Here, observability and controllability of the grid are central factors to achieve this goal, however, additional equipment such as distributed sensors and controllers

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are expected to increase the system's vulnerability due to cybersecurity issues. Here, task 4.4 will suggest adequate measures to overcome these risks.

1.2 Context and objectives of task 4.3

Task 4.3 focuses on the identification of interfaces and technical requirements to enable consumer participation. Here, the integration plan outlined in tasks 4.1 and 4.2 is used as a basis for the definition of the market interfaces on the consumer side to formulate recommendations for the OneNet development. Furthermore, some aspects of consumer integration such as consumer engagement and incentives are addressed to complete the overview.

A consumer acting as a prosumer or offering system services to the market can be considered a standard service provider with a defined API. Based on the review of previous projects such as CoordiNet, Platone, EU-SysFlex, etc., but also including the outcome from the BRIDGE Working Group on Consumer and Citizen Engagement, and the interaction with the OneNet demos and the other WPs, the corresponding requirements on the consumer side are defined.

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2 Methodology

A central outcome of the preliminary work in WP4 is the analysis of common requirements and interaction among tasks to improve the efficiency and exploit synergies among tasks 4.1, 4.2 and 4.3. As the focus of the WP is TSO-DSO-consumer interaction, the same processes, data exchange and interfaces are discussed in each task from the corresponding perspective, TSO for task 4.1, DSO for task 4.2 and consumer perspective for task 4.3. Therefore, the three tasks have created a common ground to use as a basis for the work of each task reflecting the specifics of their context.

2.1 Selection of projects

This task builds on the work in previously completed and ongoing large-scale EU H2020 projects. The fact that the OneNet consortium includes partners from different fields, with different background, competences and expertise, most often directly involved in such projects was highly beneficial in the process for the selection of the projects to review.

In the first step, the projects included in the BRIDGE consumer methodology and the projects reviewed in tasks 4.1 and 4.2 were included for the pre-selection. In a joint discussion with all WP4 partners, the already reviewed projects in tasks 4.1 and 4.2 were sorted to filter out those projects, which do not consider the consumer perspective. Furthermore, a selected number of the projects reviewed for the BRIDGE methodology were included. The initial pool of projects included Compile, WiseGRID, InteGrid, CoordiNet, EU-SysFlex, PlatOne, EUniversal, INTERRFACE, TDX-Assist, FLEXICIENCY, InterConnect, Interflex, Flex4Grid, ELSA, GOFLEX, React, MuseGrids, Empower, Crossbow, Farcross, FlexiGrid and Flexitranstore. In the next step, the latter four projects (Crossbow, Farcross, FlexiGrid and Flexitranstore) were discarded, as involved partners declared that these projects consider no significant involvement of the end consumers. The remaining projects were assigned to the WP4 partners for review based on the questionnaire presented in the previous section. As different demonstrations within one project might define different requirements and even drive the developments in different directions, the questionnaire was filled out for each demonstration site instead of one per project.

As an outcome of this preliminary step, the analysis was further refined to assess the relevance of each project for the following aspects: consumer type and engagement, interfaces, communication and data exchange, as well as TSO-DSO-consumer interoperability. Finally, the findings in the projects were compiled and analyzed in order to present the state of the art in this document, identify gaps and ambiguities and draw first conclusions from the findings as a preparatory step to the definition of recommendations for OneNet.

2.2 BRIDGE methodology: consumer

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The BRIDGE initiative of the EU works with ongoing and completed projects to support the sharing of knowledge gained within the projects and to exploit resources more efficiently by increasing the visibility of their outcome. The working group Consumer and Citizen Engagement issued a final report in June 2019[1], which is a valuable resource for the work on the consumer perspective in the TSO-DSO-consumer interoperability. The main recommendations formulated by the working group are the following: firstly, customer engagement needs a dynamic and flexible framework to function and, secondly, customer engagement should be structured in a cyclic manner, where feedback loops and iterations are possible. The findings of the report are summarized in the following categories:

- Customer Engagement Cycle
- Barriers to Implementation and Customers Analysis
- Drivers for Speeding-Up Engagement
- Definitions and Best Practices

The defined BRIDGE methodology and approach do not fully reflect the focus of task 4.3, for example, the consumer engagement cycle is outside the scope of WP4, as well as the speeding-up of the engagement and the corresponding drivers. However, the guidelines are used as a general basis for the analysis of previous projects and will be included in the final recommendations of task 4.3 for flexibility integration and consumer interaction.

Another highly relevant BRIDGE outcome is the report on "Exploration of citizen engagement methodologies in European R&I projects" [2] from February 2021[2], which deals with the following aspects:

- Socio-economic drivers of engagement
- Group building
- Governance and organisational models
- Assessment of engagement
- Smart tools.

The work on the socio-economic drivers of engagement deals with incentive strategies implemented by projects to ensure the participation and involvement of consumers. The relevant chapter focuses on user groupings to inform engagement strategy building, and adaptation to COVID-19 to help projects improve and adapt their engagement strategies. The first aspect presents a grouping of consumers in five categories (private consumers, collective consumers, industrial consumers and others) and an analysis of their specific needs/motivation/behaviour. The consumer categories served as a basis for the discussion of the different consumer types for the work in task 4.3.

[1] https://bridge-smart-grid-storage-systems-digital-projects.ec.europa.eu/sites/default/files/documents/working-groups/BRIDGE-Customer-Engagement-WG-Findings-and-Reco-July-2019.pdf

[2] https://ec.europa.eu/energy/sites/default/files/documents/bridge_wg_consumer_and_citizen_engagement_report_2020-2021.pdf

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The group building aspect evaluates ways to build consumer groups as part of R&I projects based on surveys among ongoing projects similarly to how it was done in the BRIDGE project. The outcome is the definition of phases in the group building process: starting phase, operating phase, and sustainability phase. Furthermore, the survey showed that only a few projects were established and used a methodology for group building. Therefore, within WP4, the establishment of a solid methodology to analyze previous work and to enable the interoperability of flexibility assets by integrating and consolidating the lessons learned from international projects, use cases, maintaining a set of recommendations, and best practices was of central importance.

The third aspect, Governance and Organizational models, explores currently used organization models for community-based initiatives, focused on governance principles and their implementation in energy communities.

The aspects of the Assessment of engagement and Smart tools were not directly relevant to the work in task 4.3 regarding the integration of consumers, nevertheless, they offered an informative overview of the best practices and recent developments in this field, and were indirectly included in the state-of-the-art review in Chapter 3.

2.3 Methodology

The applied methodology and generic business processes are developed in task 4.1 and described in detail in deliverable 4.1 with the objective to set a stable methodology that will be used to build up results based on the outcomes of the past projects and integrating at the same time the outcomes of the new projects. Furthermore, this methodology will also enforce the interoperability of flexibility assets by integrating and consolidating the lessons learned from international projects, use cases, maintaining a set of recommendations and best practices. The methodology will use the introduced reference framework to integrate the input from more projects and add new examples on the existing framework based on the use cases effectively implemented by other projects.

In order to extract lessons and recommendations from previous H2020 projects, this task used the BRIDGE methodology, which the data management working group proposed. This methodology aims to create a common base to compare and harmonize outcomes from projects that developed different technical solutions. The underlying idea of the Bridge methodology is to design a generic business process comprised of functions and interfaces. From this methodology, it is possible to map each project's use cases and architecture to identify the existing solutions and gaps.

As also described in D4.1 (section 2.2), this process represents the characterization of data exchange between business roles (e.g., aggregator, DSO, TSO, market operator). In turn, each function enables the characterization of the data exchange between roles (interfaces). Applying the generic business process enables the analysis of

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the function and information layers of the SGAM (Smart Grid Architecture Model). Accordingly, this methodology is independent of any technical solution adopted in each project, enabling the design of a simple sequence diagram to describe the interactions among business roles in each use case. As depicted in Figure 2-1, each row is a role in the sequence diagram, the rectangles correspond to the function and the arrows represent data exchange.

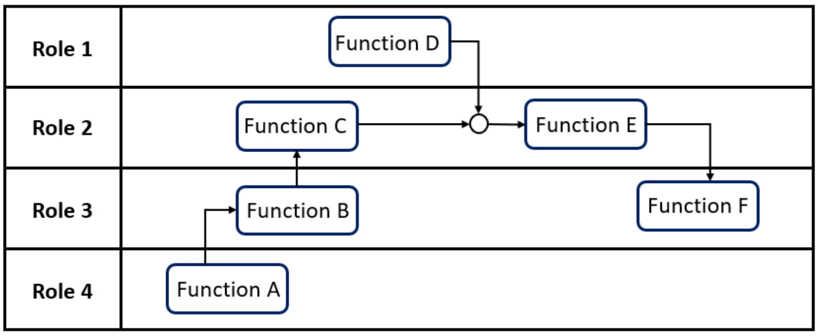

Figure 2-1 Example of a generic business process diagram.

In order to analyze the use cases from previous H2020 projects, two templates were used to describe the functions and interfaces, as depicted in Figure 2-2 and Figure 2-3. The template for function description is represented in Figure 2-2, while Figure 2-3 depicts the template for interface description. These tables complement the sequence diagram design for each use case selected from the H2020 projects.

X1 / Function name	
Description	This cell describes the purpose of the function.
Inputs / Outputs	This cell indicates the inputs received from the previous function and the outputs provided to the following function.
Subfunction	This cell describes the decomposition of the function into subfunctions.

Figure 2-2 Template for function description

X1 -> Y1	
Involved Roles	This cell lists the involved roles
List of exchanged data	This cell lists the exchanged data, e.g., "Flexibility offer"
Data Models	This cell indicates the standards used for data exchange.
Communication Protocols	This cell indicates the standard of communication protocols used for data exchange.

Figure 2-3 Template for interface description

By using this mapping, several aspects can be featured:

- identification of the solutions and standards used for data exchange;
- understand if the standard solutions are adopted and to what extent they need to have modifications to accommodate the needs of each use case for the procurement of flexibility services;
- gaps and lack of solutions for specific functions or interfaces;

The described reference framework enables the comparison and harmonization of the contributions from different projects with different technical solutions (see section 2.1 in deliverable 4.1). The generic use cases are presented in section 2.2 of the mid-term report of task 4.1, defined as a sequence of events that describes the use of a particular system. The defined generic business process follows the focus of task 4.1 to identify data exchange and interfaces at the TSO level. Therefore, here it is adapted to the consumer perspective of task 4.3.

2.4 Questionnaire

The questionnaire used to analyze previous projects is included in Annex I. It covers 8 sections that correspond to the sections of Chapter 3 in this document, namely consumer type, consumer engagement, consumer interaction, interfaces, tools, hardware requirements, communication and data exchange, and data analytics.

The first section considered types of consumers that were addressed, with detailed questions on definitions, actors and roles. Existing and explicitly defined roles such as consumer, customer, prosumer, energy community, etc. are listed. Furthermore, user profiles, their mapping to the roles and clustering strategies used, were addressed.

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The second section on consumer engagement aimed to collect information on strategies for consumer involvement including monetary (billing and energy plans), social and environmental, and the corresponding business models, in case the project defined any.

The third section covered the consumer interactions, which were addressed within each project, in the sense of the consideration and support of the interaction among consumers and consumer groups in different constellations, such as a consumer to consumer, consumer to group, consumer to platform, etc. Furthermore, the technical requirements and implementation of the interaction integration were addressed. Finally, different organizational activities such as training and educational activities and support services were addressed.

The fourth, fifth and sixth sections included questions to evaluate the implemented consumer-side interfaces between consumers and markets or grid operators in terms of information models, timing requirements and interaction sequences (section 4). Furthermore, interface-related tools were asked to be listed such as forecasting, data exchange, bid selection/optimization, pre-qualification, settlement, flexibility registers, state estimation, coordination, baseline calculation tools, etc. (section 5).

The seventh section included questions on communication and data exchange that aimed at collecting information on the technical requirements, standards, protocols and data models, but also on different hierarchies and constellations in terms of communication with the consumer (centralized, decentralized, distributed, agent-based, data aggregator, local optimization).

The eighth section addressed general aspects of implemented data privacy and data protection measures, as well as applied data analytics strategies and the corresponding level at which they were applied.

2.5 Engagement with demonstrators

During the whole development of this report, the team has worked closely with the demonstrators in OneNet. In addition to the questionnaire discussed above, the team also interacted with the different demonstrators to ensure a complete and up-to-date image of their work.

In addition to clarification e-mails, this interaction included meetings with the relevant partners involved in the demos to both complete the information already available in the use cases developed by the demonstrators (as reviewed in task 2.3) and update it when necessary. Furthermore, a questionnaire has been developed to identify the current state of the corresponding demo, and to gather information on applied BUC and SUC, developed products and services, data exchange at TSO, DSO and consumer level, consumer integration, etc. The questionnaire was circulated among the demos as a first step of the analysis of the requirements of the demos. The questionnaire can be found in Annex III.

These interactions allowed that the demonstrators reviewed the initial analysis of the business cases described above to ensure it is consistent with their current view of their work. Furthermore, it allowed this task to explain our objectives and the information that would be required to complete our analysis, which facilitated that they provide this information in an efficient manner.

2.6 UC consolidation

One of the defined goals of task 4.3 is to enable a TSO-DSO-consumer integration. In order to do so, the UC reviews from different perspectives have been consolidated in order to identify the effect of gaps, barriers and enablers at each level on the other actors, and how measures at one level would affect the rest of the system. The approach is illustrated in Figure 4, where the information from the analysis of UC A from all three perspectives is combined to draw conclusion from the system-level point of view.

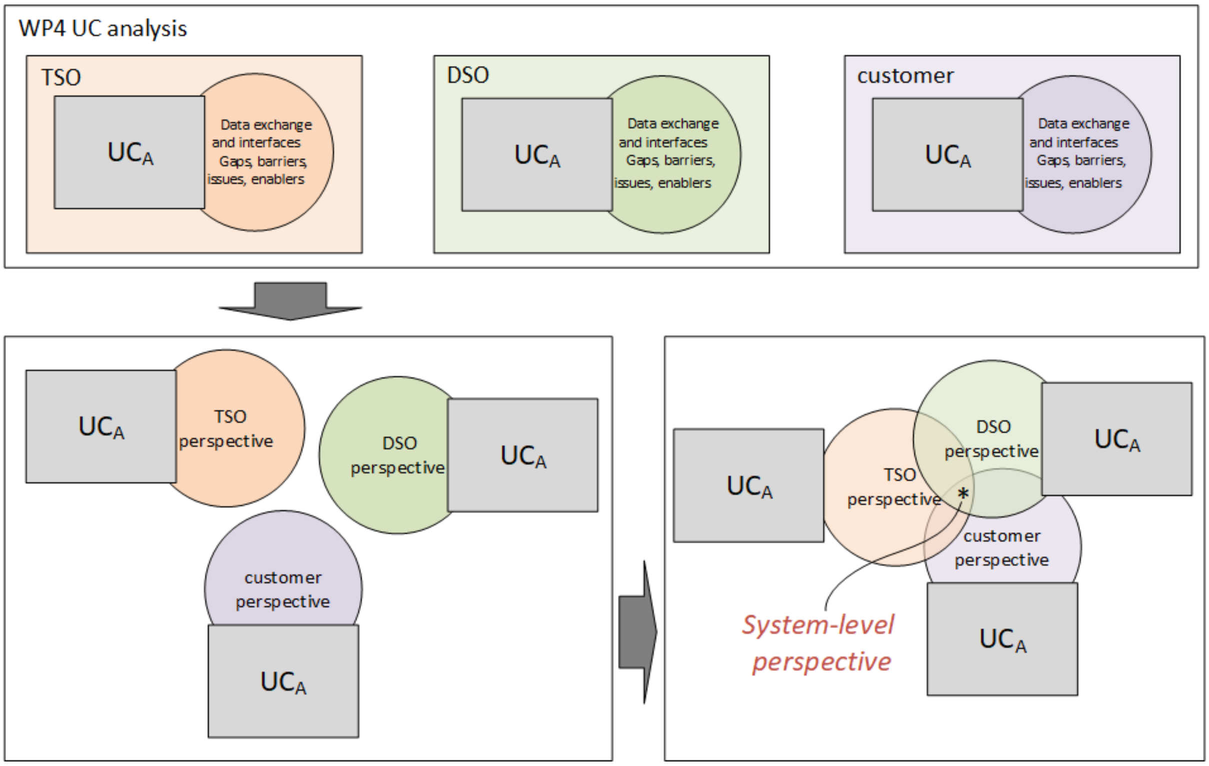

Figure 2-4 Consolidation of the UC analysis from different perspectives

Furthermore, the level-specific gaps and recommendations were reviewed for their meaning and the effect on the system and listed together with the conclusions and guidelines for interoperability in section 5.3.

2.7 GRIFOn

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OneNet aims to go beyond the conventional solutions developed within a project and provide a platform for discussion and cooperation. The forum GRIFOn is one of the mechanisms for inclusion of a wide range of stakeholders across Europe. The goal is to involved experts with diverse background, expertise and experience from academia, industry and politics to develop mature solutions based on an European consensus, which can be rapidly brought to the market after the end of the project and enable quick standardisation.

In order to benefit from the expertise of European experts for the work of WP4, a GRIFOn event exclusively on the topics of TSO-DSO-consumer interoperability was organized and took place on 6.5.2022. To enable active participation, the discussion was organized in small groups of up to 12 participants, with three groups for each task and actor (TSO, DSO and consumer). Each group discussed four different topics, three on data exchange issues from the corresponding perspective and one question on cyber security. The results are presented in section 3.4.2 and discussed in Chapter 5.

2.8 Gaps, requirements and implementation recommendations

The complexity of the data exchanges related to the flexibility markets requires the settlement of proper guidelines and recommendations for addressing data exchange processes between not only two entities but among different roles, multilateral instead of bilateral. The methodology presented in this chapter aims to identify gaps in the data exchange and interfaces for the TSO-DSO-Consumer interactions that act as barriers to fostering the flexibility markets. Considering the task 4.3 context, the gaps identified in this report are addressed from the consumer standpoint. For that purpose, the analysis of the UC from the selected H2020 projects and OneNet project examines the data exchange standards used in those pilots. This analysis identifies the most used ones in the selected H2020 projects. It provides recommendations for changes and improvements to the standards for ensuring the materialization of the European flexibility markets with the active participation of the consumers, either individually or collectively (aggregation). In particular, the identification of gaps was done for existing standards to understand how extensively they cover the data exchange requirements within the flexibility markets. Through the developed methodology, this deliverable identifies a set of requirements regarding data model standards and communication protocols to facilitate the data exchange processes and interoperability among grid operators (TSOs and DSOs) and consumers (prosumers, aggregators).

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3 State of the art

3.1 Consumer

The present section assesses the various consumer types considered in the H2020 projects under revision.

Among the projects there is a variety of terms and approaches to characterise consumers or consumer groups. Although in most of the projects a "consumer" is defined as a citizen or a group of citizens, some projects also include SMEs or municipalities or corporate consumers (e.g. power companies).

3.1.1 Consumer types

In an attempt to summarize the terms for consumers most often used in the reviewed projects, the following categories were identified:

- **Passive consumers**, i.e., traditional consumers as entities that only consume electrical energy and their intervention potential in flexibility processed is, if at all, rather limited to demand response measures. This category of consumers can be sub-divided into four further main categories:
    - Residential consumers (households)
    - Business consumers (office buildings, SMEs)
    - Business consumers in the field of transportation
    - Large industrial consumers
- **Prosumers**, i.e. consumers as above that possess generation or storage units and can provide flexibility to the grid
- **Utilities** (including power plants) that can be Consumers within a flexibility process.

This document focuses on the consumers, prosumers and partly aggregators and does not include utilities in the review and analysis.

Consumers can be classified according to the form of their consumption, like:

- EV consumers
- Heat Pumps consumers
- Etc.

Consumer Groups can form in several ways, like:

- Energy Communities (or Energy Cooperatives) as per local legislation
- Municipalities, in terms of a collective scheme of consumers in a certain region
- Aggregators

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3.1.2 Role models

Practically all projects under consideration elevate the role of consumers from a purely "passive" state, i.e. just the last part of the grid, to a more "active" state, i.e. participating somehow towards grid stability and efficiency either as prosumers or in demand response schemes or even aligning local generation and consumption through grouping like in energy cooperatives/communities.

The case of energy communities and clustered flexibility is covered by the role of an Aggregator. This deliverable focuses on the interface between the flexibility seller and their byers. In this context, the Aggregator is a potential seller of flexibility, likely to take a more professional approach to engage in the market than individual consumers.

3.1.3 Context, frame conditions, limitations

It is essential to note that the various consumer types considered are rather of an intuitive nature and always dependent on the scope and view of the project. As such, the terms **consumer** and **customer** (in some few cases also the term citizen) are being sometimes used (not only in those projects but also in relevant literature) as synonyms. In some cases, the consumer/customer is perceived as a natural person, in some other cases as a household or group (such as households in a building), and in other cases as legal entities (commercial customers/consumers).

Almost the same applies to the term **prosumer**. A prosumer is a consumer who can produce and/or sell products or services like the ones that they consume but again it is not always clearly (and consistently) defined whether a consumer who participates in a demand response scheme can also be considered as a prosumer, or a prosumer must have at least one generation or storage unit that feeds electricity to the grid.

Furthermore, there is an issue whether large prosumers (such as an industrial unit that covers partially its energy needs from a large power production unit of any kind and is in position to inject excess energy to the grid) can be considered as such, or where the limit shall be set. In general, it might be necessary to develop a common vocabulary, especially as the EU envisages cross-sector interoperability, and similar terms could have a different meaning in other sectors. In the following the terms used for consumers in various official documents in the EU framework are presented.

The Bridge Report on Consumer Engagement

The BRIDGE Consumer and Citizen Engagement Working Group in its report *"Exploration of citizen engagement methodologies in European R&I projects" [2]* identifies the main consumer types from the socio-economic point of view as follows:

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- collective consumers
    - private buildings
    - public buildings
- industrial consumers
- others

EU framework and ENTSOe Definitions

EU Regulation 2017/2394 [3] on enforcement of consumer protection laws, defines a consumer as follows: 'consumer' means any natural person who is acting for purposes which are outside his trade, business, craft or profession.

In ENTSOe's Harmonized Electricity Market Role Model (HEMRM) [4], the consumer is a party that consumes electricity and (additional information): a Type of Party Connected to the Grid.

The Renewables Energy Directive (RED II – 2018/2001) [5] defines the self-consumer as follows: 'renewables self-consumer' means a final customer operating within its premises located within confined boundaries or, where permitted by a Member State, within other premises, who generates renewable electricity for its own consumption, and who may store or sell self-generated renewable electricity, provided that, for a non-household renewables self-consumer, those activities do not constitute its primary commercial or professional activity;

The Internal Electricity Market Directive (2019/944) [6] (IEMD) highlights that: **'customer'** means a wholesale or final customer of electricity; where in this regard the customer might (if wholesale) be a re-seller as specified: **'wholesale customer'** means a natural or legal person who purchases electricity for the purpose of resale inside or outside the system where that person is established; and a '**final customer'** means a customer who purchases electricity for own use.

Out of the above, it is the final customer of IEMD that rather corresponds to the consumer as defined in Renewables Directive 2017/2394 [7].

In more detail, according to article 2 of the IEMD:

'household customer': a customer who purchases electricity for the customer's own household consumption, excluding commercial or professional activities;[3]

[3] Although not stated but logically a *household customer* can only be a *final customer*

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'non-household customer': a natural or legal person who purchases electricity that is not for own household use, including producers, industrial customers, small and medium-sized enterprises, businesses and wholesale customers;

'active customer': a final customer, or a group of jointly acting final customers, who consumes or stores electricity generated within its premises located within confined boundaries or, where permitted by a Member State, within other premises, or who sells self-generated electricity or participates in flexibility or energy efficiency schemes, provided that those activities do not constitute its primary commercial or professional activity;

This term approaches the generally used (and not defined in the framework) term prosumer, which is derived from the combination of the terms producer and consumer. In the IEMD and HEMRM a producer is described as a party (natural or legal person) that generates electricity (a type of Party Connected to the Grid).

Finally, due to the lack of official terminology and the variety of different circumstances and involved actors in each scheme, the terminology to describe consumer types in the projects, in EU acts and other initiatives is not consistent. Within the project OneNet, the terms consumer and customer are both used in a similar context. Here, the use of the terminology could have been defined in a clearer way, referring to a customer in case the actors stand in a business relationship such as between an energy provider or the market and a buyer or a seller, and to a consumer in case a theoretical construct is discussed. As this document focuses on the interoperability and integration of small FSPs with limited flexibility capacity and economical aspects such as the business relationships among the actors or billing and incentives are neglected, the term consumer is used throughout the complete document.

However, we identify that in the electricity domain a harmonization of the terms could lead to a more reliable common understanding and subsequently to efficiency in modeling Use Cases or even developing systems and achieving interoperability.

3.2 Consumer engagement strategies

3.2.1 Strategies and tools

The data required to develop strategies and tools for consumer engagement have been gathered from several EU projects based on a questionnaire as described above in section 2.4 of this document. It was observed that each project has established different strategies and tools for consumer involvement, which varied according to the target consumer types and the overall aims and organizations of the project.

To start with, some projects, such as the H2020 project Coordinet, differentiate their consumer engagement strategies according to the consumer types: Power companies or large organizations, large and medium size

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consumers and aggregated small consumers [9]. It was observed that power companies and large organizations are easier to coordinate and engage since they usually have energy professionals exclusively dedicated to energy management, while for small consumers it was recommended to involve aggregators to coordinate and manage the consumer interaction and flexibility activation.

The COMPILE project, which aimed at the development of energy communities in the target regions, based their consumer involvement strategy on three pillars: The Energy Community Toolkit that will provide tools and methods to support the development of energy communities and is adjusted to the specific context of the pilot sites, a training methodology that will allow building capacities in the local communities to support them in the development of their energy communities, and a network of experts and mentors to support the future deployment of energy communities and multiply their deployment.

Some projects, such as MUSEGRIDS [12] focused at first on consumer motivation informing them of RES and the opportunities they offer such as environmental improvement and innovation. Secondly, project objectives and activities were communicated to local media presenting the results of the energy habit survey and transmitting knowledge in flexible technologies, social results and benefits. The last part of the engagement strategy was more participatory in the sense of workshops and feedback collected among the participants.

A very constructive example of a consumer engagement strategy that was divided into 4 stages can be found in the REACT project [11]. The community engagement framework of this project is depicted in Figure 3-1.

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Timeline	Stage one Month1-12 Meeting the communities	Stage two Month 6-48 Recruiting & Engagement	Stage three Month 24-48 Demonstrating the potential	Stage four Month 36 -48 Replication & Sustainability
Objective	Understanding community context & introducing the REACT	Customized strategies to involve the communities and raise awareness	Show potential to locals and follower islands. Learn. 2nd Recruitment.	Involve follower islands and guarantee REACT's sustainability.
Actions (Focus)	Interviews Community events. Surveys	Community events involving public & relevant institutions Creation of online communities	In situ demos, Collect user feedback Keep awareness & engagement Involve larger media outlets Share results	Sustainability Training (events) Innovation workshops with followers Presentations at relevant events
Materials & Channels	Website Social media channels Project presentation Roll-up Project presentation brochure	Website + blog Weekly content (tips & tricks) SM channel. Customized recruiting brochures Customized presentations (events & video). Recruiting videos Learning materials (Gamification)	Website + blog Weekly content (demonstrations) Keep all channels active. Real videos (1 per pilot + global) Assessment & TAM Testimonials & Experiences Collect feedback from SM	Website + blog Weekly content User-oriented manuals for recruits Customized posters (1 per follower island) Customized presentations Final project video Brochure Roll-up

Figure 3-1 REACT community engagement framework [11]

Some common elements of the different consumer involvement strategies found in the reviewed EU projects for end-users included informing the target group consumers about their participation and its benefits before the demonstration started [13]. The early information of the consumers in the demonstration regions was considered very important, as involving them too late can lead to people feeling disconnected and ignored. This also leaves room for speculation (especially in rural areas) or may lead to high expectations. It was also strongly recommended to involve representatives of the local community, for example, mayors, local councils or others, as they can provide feedback on the general mood and acceptance of their community. In addition, they can support the creation of acceptance and give hints about local do's and don'ts.

Furthermore, most projects followed a participatory and multi-stakeholder engagement approach and used several tools to enhance the consumers' involvement in the project. In more detail, user-engagement workshops were planned addressing each time different consumer types: local key-stakeholders and large commercial prosumers, residential consumers, energy communities. Some projects also produced individual summary reports of the demo for each consumer and online questionnaires and surveys that contained short questions about the demo experiences and the possibility to give open feedback and suggestions as done in the Finnish demo of the project EU-SysFlex [13].

Some projects such as Integrid [14] also held workshops for consumers that focused on energy efficiency and energy awareness or on the dissemination of the demo's activities in the Slovenian demo. Social media posts and other communication activities of the demonstrators also proved useful to end consumers as shown in the Portuguese demo. Finally, some projects provided for continuous support to be granted to consumers until the end of the project, for example, through a permanent communication channel and periodic visits.

3.2.2 Incentives (monetary, environmental, social)

In terms of the incentives that were provided as part of the consumer engagement strategy, several projects offered monetary, social and environmental incentives to the consumers involved in the project and the demos. With regards to the environmental incentives, there were some environmental values that consumers considered important, such as interest in the consumption change, exploitation of energy from domestic renewable sources and increased spread of energy efficiency and flexibility solutions in Europe as done in the Slovenian demo of the project Flex4Grid [15].

The economic benefits provided by several projects include, among others, savings on operating costs through more efficient data exchange, savings on costs of consumer portal implementation, savings on the cost of integrating different energy Data Hubs and lower electricity bills and/or extra revenues (if the consumers own flexible assets), as in the data management demonstration [13]. Moreover, in some pilot sites, dynamic pricing was offered. In the Flex4Grid Slovenian demo [15], for users who were responsive, the price of the network fee resulted to be 11% lower compared to the standard price. The use of variable network tariffs instead of a flat network tariff by the DSO is considered to incentivise certain behaviours from DERs' owners, which will lead to an optimal dispatch with the least possible RES generation and load curtailed, as presented in the Greek demo in the project Platone [15]. In addition, some projects provided for minor economic benefits, such as participation in a lottery: all the participants could participate in the lottery that drew some prizes.

Finally, there were projects that offered limited financial benefits to participants, but large social benefits. To start with, several projects offered improved data security and empowerment to consumers, as they had better control over their data usage. For instance, participants who used the Flex4Grid mobile were able to see the consumption of their household on daily, monthly and yearly level and, thus, had detailed insights into their electricity consumption [15]. Other social incentives included lower energy prices for all European citizens by increasing competition and the development of an entrepreneurial ecosystem [13]. An incentive for consumers to participate in the EU-Sys Flex Finish demo was the possibility to participate in the development of new solutions and in flexibility provision when the power system needs it.

3.2.3 Organizational forms (training, educational activities, support services)

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Several of the reviewed projects considered organisational activities such as training and educational activities or support services. A very interesting training technique was applied in the COMPILE project. The task 4.3. focused on the training of local energy community actors in the pilot sites (i.e., "Train the trainers") that will allow to build capacities in the local communities to support them in the development of their energy communities. As preparatory work, the COMPILE partners used the PESTEL analysis (they assessed the Political, Economic, Social and Technological, Environmental and Legal context) and stakeholder mapping. They also listed adjacent energy communities and the municipal transition plans. COMPILE organised trainers workshops and community engagement workshops for the pilot sites to inform and train the demo leaders and local community leaders on the tools of the COMPILE Energy Community and technical toolkits. To increase the impact of those workshops, they will invite the User Group members to encourage replication. The participants will be invited to join the Replication Group of COMPILE's network of stakeholders.

Other projects provided safety instructions on the installation and operation of battery and power electronic systems, user manuals and the use of apps specifically designed for the project. Moreover, education activities included awareness raising and capacity building events, such as local sustainability training workshops, educational webinars and demo visits. In the case of EMPOWER, these workshops attracted international business leaders and made them aware of the business opportunities that arose from the project. Besides workshops, the dissemination actions covered an extensive list of written publications (journal papers, press releases, non-scientific publications), presentations in workshops, conferences and meetings.

3.2.4 Applications, acceptance, performance evaluation

In regard of application, acceptance and performance evaluation, there is still a significant need for research and development considering the reviewed projects.

In general, the applications developed for consumers are smart home applications in which consumers have access to the consumption of their home equipment. As an example, in the Flex4Grid project enough consumers were motivated to participate in the project without the application of incentives [15]. Similarly, in the Integrid project, another application to support the energy management of residential consumers to maximise self-consumption and self-sufficiency through the use of a HEMS was developed [14]. This will be accomplished through monitoring, controlling and assessing the amount of energy that each consumer can generate, the load-shift pattern and the storage capacity in each time period. This allows consumers to explore the potential of self-consumption and electricity cost minimisation.

3.3 H2020 Projects UC Analysis

3.3.1 Projects

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As introduced in Chapter 2, within task 4.3 several H2020 projects were reviewed based on the developed questionnaire in Appendix II in section 8 to identify relevant projects with focus on consumer integration. Here, the considered project UC are presented briefly, and the details on the interfaces and data exchange are introduced in sections 3.4.1-3.4.5.

Platone [16]

The project aims to develop solutions to improve the observability of RES and distributed resources in order to fully exploit the available flexibility. Here, BUC from the Italian and the German demonstrator sites were considered relevant. In the Italian demo, the relevant UC deal with voltage control and congestion management:

- UCIT1- This use case describes the main steps to avoid voltage violations in transmission and distribution systems by exploiting flexibility resources, contemplating all the phases concerned (procurement, activation and settlement) in the day-ahead and real time flexibility market. The DSO can use flexible resources connected to the distribution system and the TSO can use flexible resources connected to distribution systems under the DSO's approval. The state estimation is assessed and monitored by the DSO in order to keep the electrical quantities within admissible ranges.
- UCIT2 - This use case describes the main steps to prevent congestion issues in transmission and distribution systems by exploiting flexibility resources, contemplating all the phases concerned (procurement, activation and settlement) in the day-ahead and real time flexibility market. The DSO can use flexible resources connected to the distribution system and the TSO can use flexible resources connected to distribution systems under the DSO's approval. The state estimation is assessed and monitored by the DSO in order to keep the electrical quantities within admissible ranges.

The sequence diagrams for the phases day-ahead and real-time prequalification and market, activation and settlement for the Italian UC of Platone are presented in Figure 3-2 to Figure 3-5.

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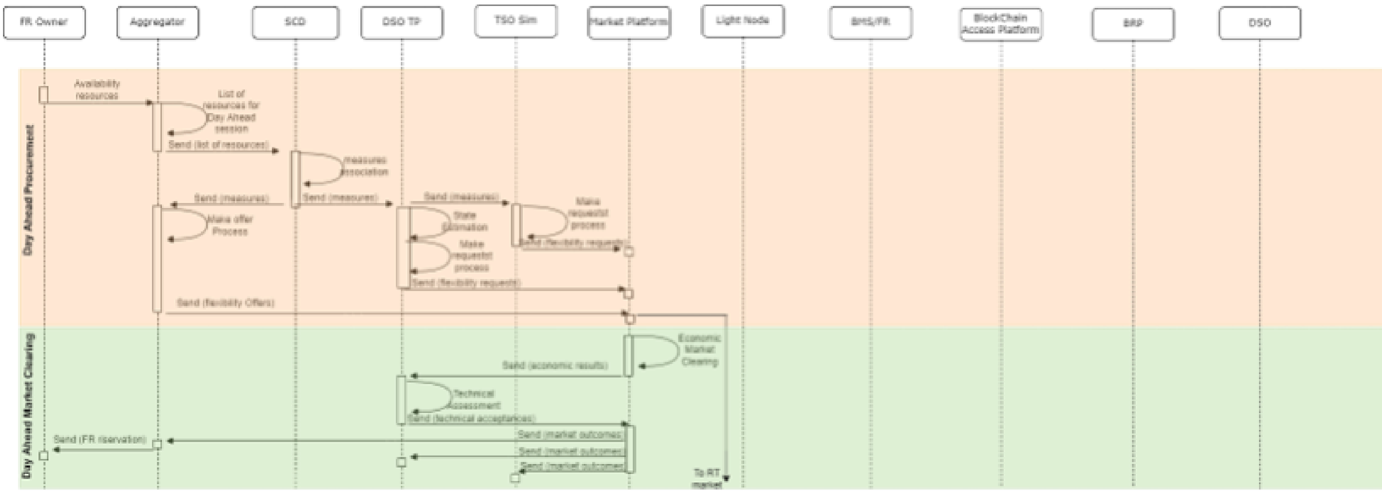

Figure 3-2 Platone UC-IT: Day-ahead prequalification and market

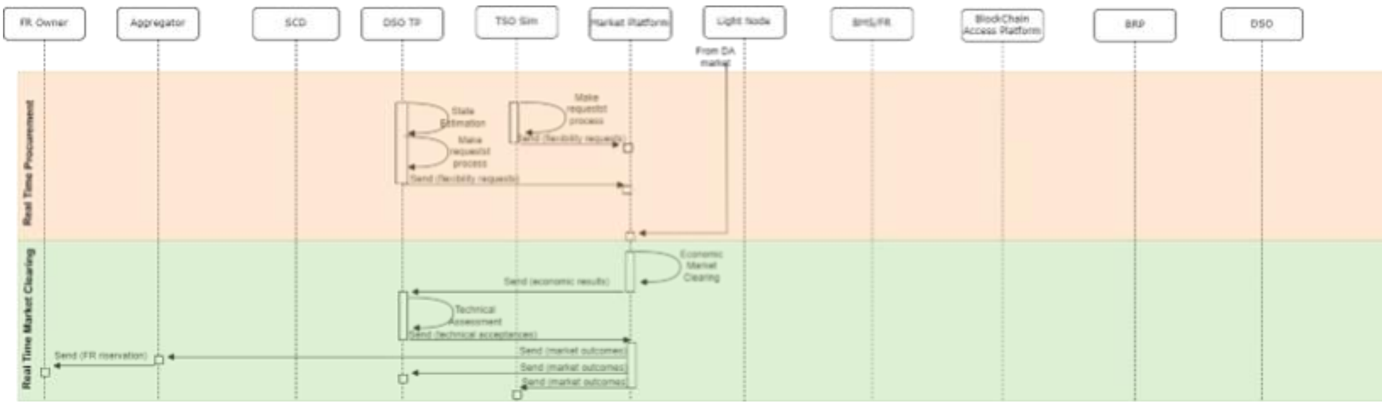

Figure 3-3 Platone UC-IT: Real-time prequalification and market

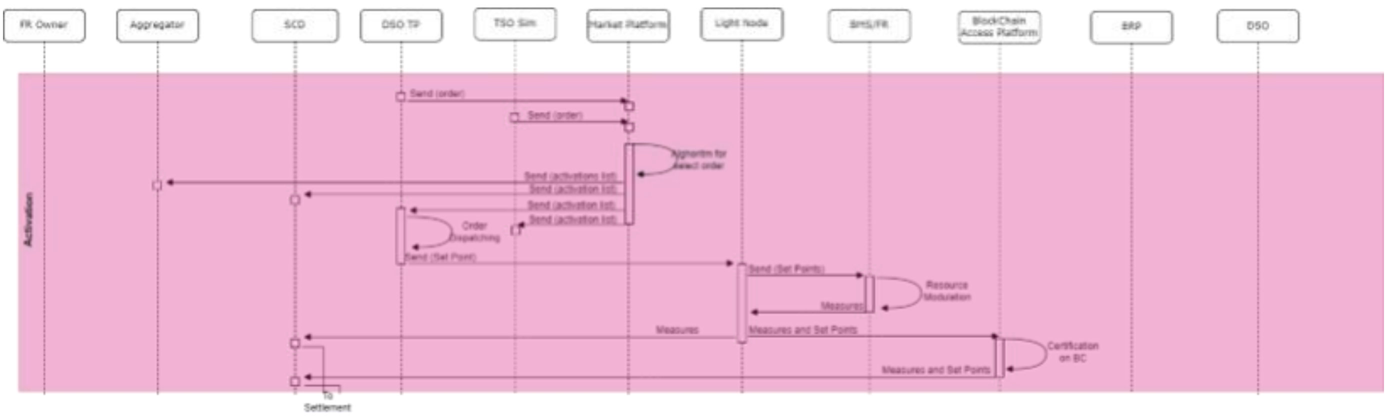

Figure 3-4 Platone UC-IT: Activation

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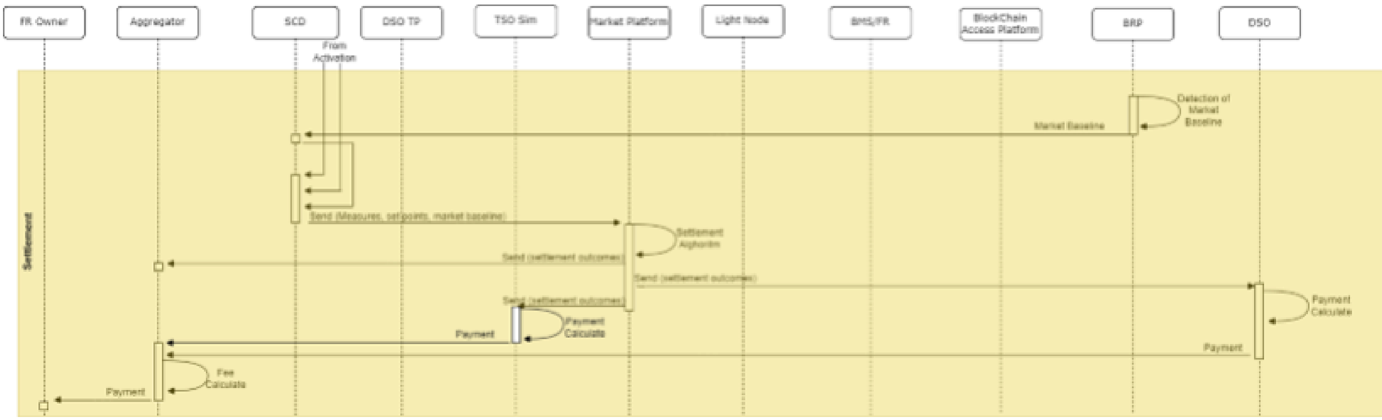

Figure 3-5 Platone UC-IT: Settlement

The German UC focuses on the integration of local energy communities in network management strategies for the stabilization and uniform utilization in the distribution grid.

In the absence of sufficient generation and storage, the community is unlikely to be self-sufficient at all times. When generation of surplus occurs, they must be exported into the distribution network. Instead of a real time energy export to the connected distribution network, energy surplus could be forecast and exported delayed as an energy package within a defined time, duration and power value for the load exchange at the LV/ MV-grid connection point. The generated energy surplus first shall be stored in local storages located within the community and be exported as an energy package delayed, when the load in the upper grid decreases.

- UC1 - Maximize consumption of local generation/Minimize demand satisfied by public grid
  - Islanding of local grid by making use of flexible loads and storages
  - Maximizing duration of islanding operation
- UC2/4 - Maintain a fixed non-zero power exchange between energy community and the distribution network for a limited duration.
- UC3 - Enabling temporary islanding even in times of energy deficit of the local community
  - Forecasting of residual energy demand of an energy community
  - Calculation of required energy packages serving energy deficits
  - Determination of power exchange schedule for the energy community for the grid connection point LV/MV (time and power of load exchange)
  - Determination of a setpoint schedule for individual local assets to meet energy community setpoint schedule
  - Execution of defined power exchange between energy community and the distribution network

The sequence diagram for the German UC is introduced in Figure 3-6.

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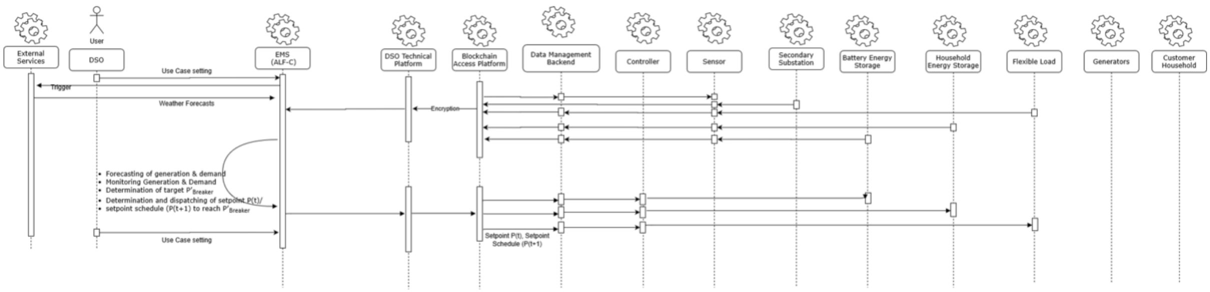

Figure 3-6 Platone German UC sequence diagram

Flex4Grid [15]

The project develops an open data and service framework to support the management of prosumer flexibility. The considered UC are the German and the Slovenian. The difference of the DSO project partners as well as topology and regulatory peculiarities of Germany and Slovenia allow testing the Flex4Grid system in different settings. The main differences in the German and Slovenian pilots are listed below:

- Germany:
  - Small scale with more complex setups and kit variances (more plugs, interfacing legacy systems (e.g. PV controllers, BEMS))
  - Flexible tariffs will be evaluated: SWB and BEW provide free kWhs as incentive for pilot consumers
  - Because of German delay in smart meter rollout no access to household consumption
- Slovenia
  - Large scale deployment with less variances: No-kit and Simple-kit
  - Access to day-minus-one household consumption from smart meters
  - Incentives for pilot users through energy saving and lottery; additional possibility of regulator initiative for higher impact

Empower [17]

The project develops a cloud platform to perform smart grid services based on machine learning. Following pilot UC were considered:

- PUC-1: Consumption and generation monitoring (Smart Energy Service Provider (SESP), Prosumers, Producers, Consumers)
- PUC-2: Production Management (SESP, Prosumers, Producers)
- PUC-3: Flexibility Management (SESP, Prosumers, Consumers)
- PUC-4: EV Charging Station Management (SESP, DSO, EV charging stations)

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- PUC-5: Battery Management (SESP, DSO, Prosumers, Consumers, Batteries)
- PUC-6: DSO Interactions Management (SESP, DSO, Prosumers, Consumers, Batteries)

EU-SysFlex [13]

The goal of the project EU-SysFlex is to enable the integration of large-scale RES and support European power system operators. Therefore, different levels of RE penetration into the European grid system are tested and analyzed. For the consumer perspective in task 4.3, solely the data management UC is considered. Here, a flexibility Platform enables to perform most functionalities required for flexibility trading in all phases - prequalification, bidding, activation (delivery), verification (part of settlement). The corresponding sequence diagram is introduced in Figure 3-7.

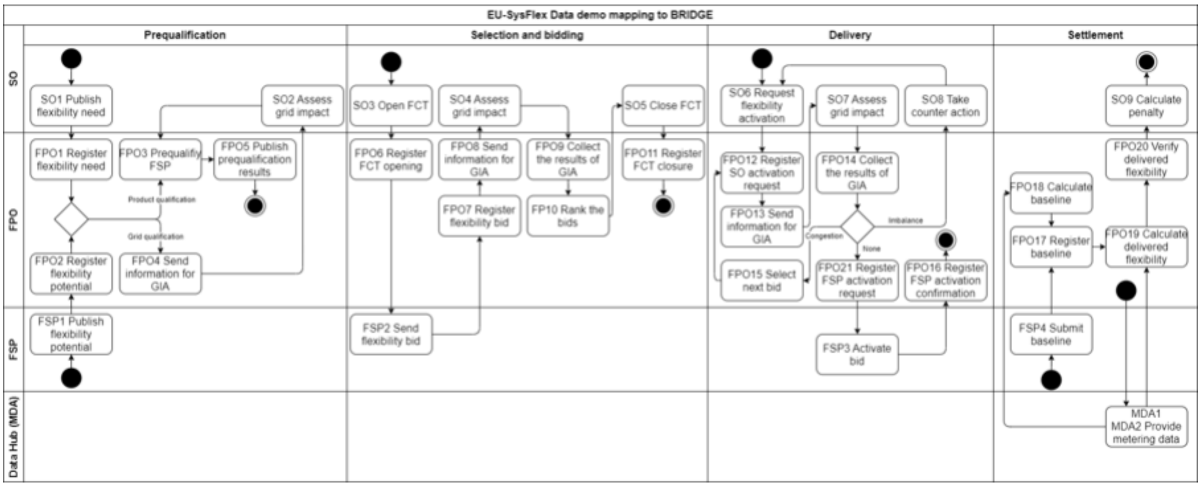

Figure 3-7 Sequence diagram for the data demo of EU-SysFlex

Coordinet [9]

Coordinet focuses on TSO-DSO-consumer coordination to demonstrate an efficient grid operation based on the joint access to a pool of resources and grid services. In task 4.3, BUC SE-1a Congestion management – Multi-level Market Model was analyzed. This BUC intends to solve congestions in the low voltage as well as medium voltage distribution grid in order to keep power flows within the subscription limits by the regional DSO and respectively TSO and within thermal limits of the lines and the transformers. A cooperation and information exchange between local DSO, regional DSO and TSO are crucial for eliminating congestions in the most efficient way, for an accurate load prognosis of the power level in the medium-voltage grid and as a market driver for flexible resources as well as for a well-functioning energy market (see Figure 3-8).

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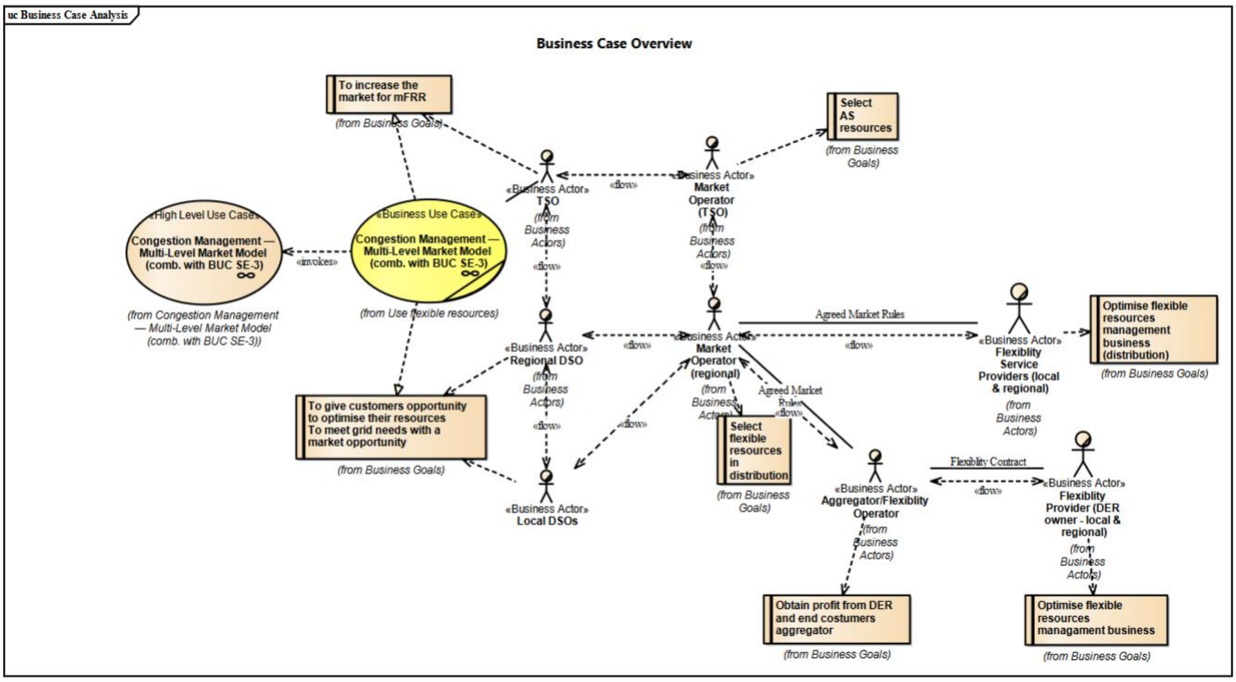

Figure 3-8 Sequence diagram for the BUC of the Swedish demo of Coordinet

InteGrid [14]

The goal of InteGrid is to connect citizens and technology providers of energy services to enable an active market facilitation and system optimization. Here, UC from the Swedish, Portuguese and Slovenian demo were analyzed:

- Integrid SL: Integrid (PUC 01.12) - Commercial virtual power plant for offering ancillary services to TSO (frequency) considering the state of the DSO grid
  Flexibility pooling is decoupled from energy supply, so aggregation is possible across many different balance responsible parties. Virtual Power Plant (VPP) system aggregates geographically distributed energy resources (DER), including renewables, demand response and storage units. Flexibility is additionally characterized by its location. The VPP system will be operated by a flexibility operator, which can be an independent market player, but also a retailer. Flexible units can be acquired and pooled by the flexibility operator. Aggregated flexibility is used for commercial purposes (mFRR or RR market operated by TSO). This is represented in the diagram in Figure 3-9.

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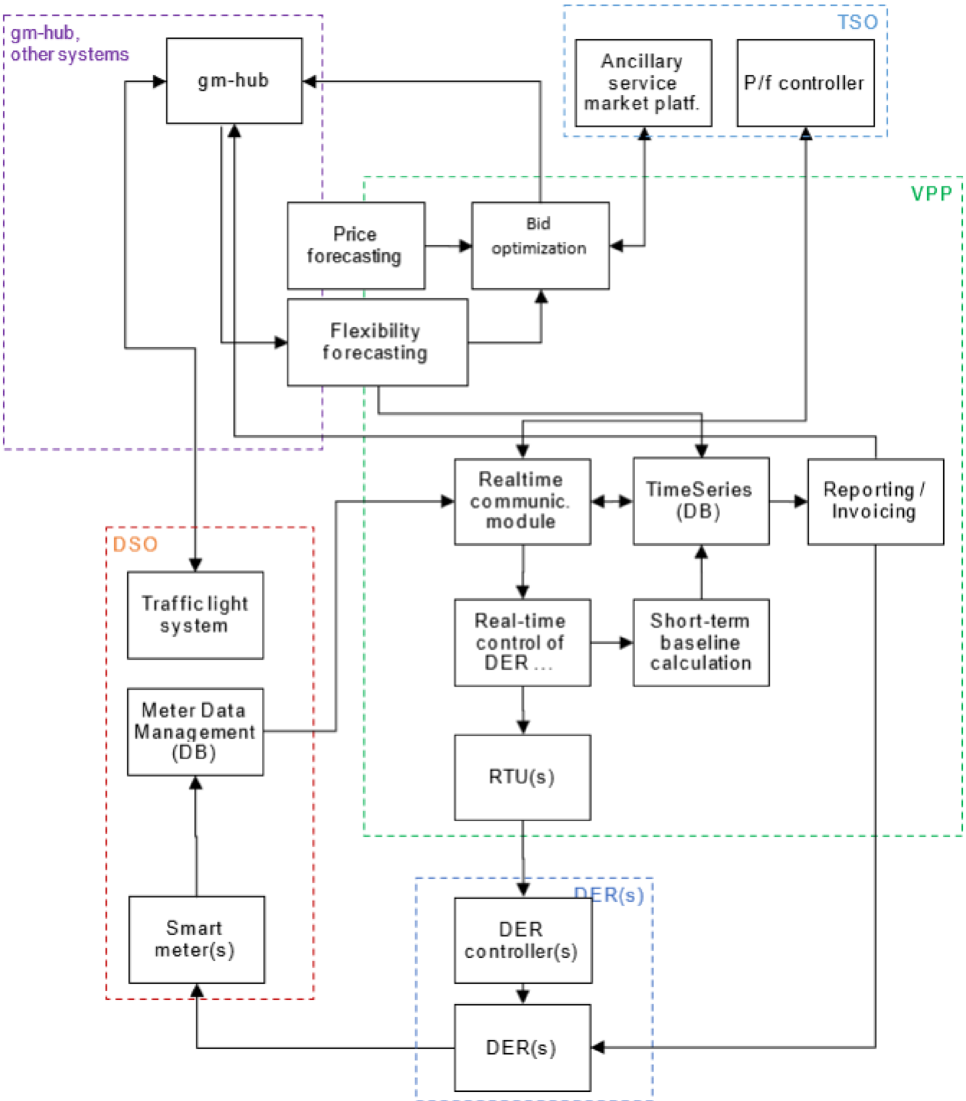

Figure 3-9 UC diagram for the Slovenian demo UC of Integrid

- InteGrid: Home Energy System Management
  This use-case presents a procedure for the provisioning of demand response that allows an optimal schedule of operation for the appliances at end-user premises through a Home Energy Management System (HEMS). This is a proactive approach aimed at making consumers energy-efficient in long-term. For this use case it was not possible to identify protocols, data exchange formats, standards and data models, given the available public information. However, the analysis was useful to understand what information was exchanged between the HEMS and meters installed at the consumers' houses and their Service Providers as depicted in Figure 3-10.

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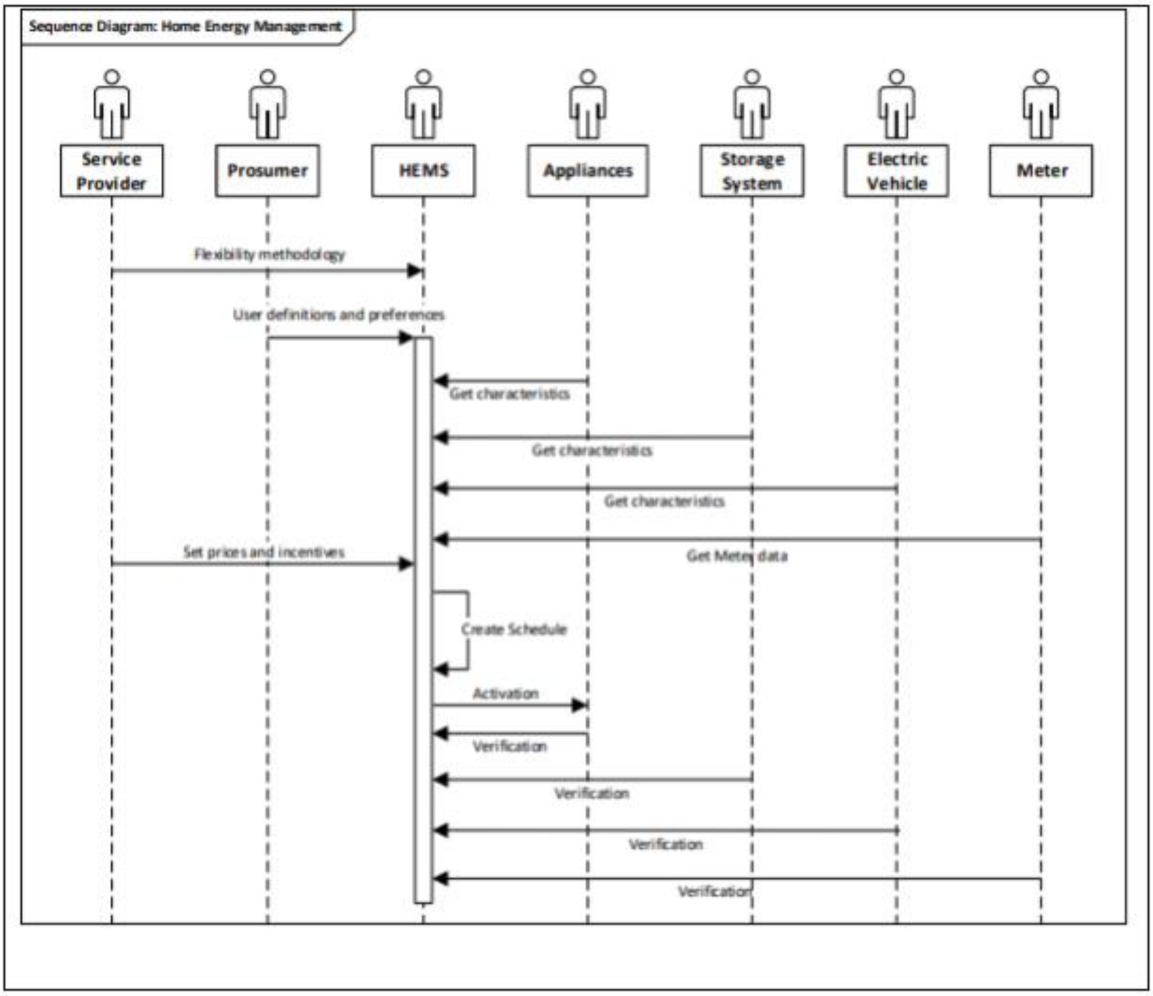

Figure 3-10 Sequence diagram for the HEMS UC of InteGrid

3.3.2 Interfaces

The identified interfaces to the consumer or aggregator are listed in Table 1.

Table 1 Identified consumer-side interfaces and actors

Project	Interfaces (Name and Description)	Actors
EU-SysFlex (Flexibility Platform demo)	Information to be exchanged: Flexibility Potential Flexibility Call for Tender Flexibility Bid Flexibility Activation Request	FSP, FPO (Flexibility Platform Operator)

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	Activated Flexibility Baseline	
Flex4Grid	DSO/End-user: The Flex4Grid system provided an interface between the DSO. Local Gateway provided an interface to the local flexibility resources at the prosumer premises. DMS interface is a gateway between Flex4Grid system and DSO systems. Main role of the DMS interface component in F4G was the integration with Advanced Metering Infrastructure (AMI) system. DMS interface collected end user energy consumption data and sent it to Prosumer Cloud Service (PCS). Flexibility Operator Interface component is a Flex4Grid "drivers' wheel" for DSO or a third party, which acts as Flexibility Aggregator/Operator and also as a data controller to have access to prosumer data it needs. 3rd Party Interface: The Flex4Grid system employed standard and open interfaces both for internal communication among its components and for external communication with third-party systems. For the latter purpose, a collection of REST APIs was implemented, third parties could use these APIs to integrate their relevant systems with Flex4Grid. End-user Interface - The End-user FO – Aggregator for Resource Planning Interface (EUI) provides graphical user interface (GUI) for the prosumers	DSO, Flexibility Operator, Prosumer
Platone IT	Aggregator – SCD for Customer List Interface Aggregator – SCD for Measures Interface Aggregator - Market for flexibility Offers Interface Market – Aggregator for Market Results Interface Market – Aggregator for Settlement Interface FR– SCD for measures Interface BRP-Aggregator for baseline	Shared Customer Database (SCD) (Flexibility Register Platform)Market Operator (MO) /Market Platform (MP)Flexibility Resources (FR)Flexibility Resources Owner (FR Owner)Aggregator/Aggregator PlatformBalance responsible party (BRP)
Coordinet	Interface FSP-DSO: REST API or webpage	FSP, DSO

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	Interface FSP-TSO: WebAPI	FSP, TSO
EMPOWER	Interface DER-SCADA Interface Prosumer – SESP Interface SCADA-SESP (Azure Event Hub Send Event)	DER SCADA Prosumer

3.3.3 Data models

As far as data models are concerned, in the previous projects two data models were identified. The Common Information Model (CIM) data model is composed of:

- IEC 61970-301, which facilitates the exchange of power system network data between organisations,
- IEC 61968-11, which allows the exchange of data between applications within an organisation and
- IEC 62325-301, which allows exchange market data between organisations.

The project EU-SysFlex proposed the "CIMification" to illustrate the need for and benefits of further interoperability through a single information model like CIM, since defining CIM canonical data model will facilitate cross-sector data exchange, e.g. by extending CIM and/or integrating other sectors' canonical data models with CIM. Furthermore, CIM supports European regulation since 2010 with CGMES (Common Grid Model Exchange Standard) 1.0 profiles, and with ESMP (European Style Market Profile) profiles since 2011. For the German demonstration, the Common Grid Model Exchange Specification is such a profile of CIM and has been used. It is dedicated to the exchange of grid information between TSOs in Europe for performing European wide power flow calculations and analysis and to describe the data exchange within the Generation Load Data Provision Methodology (GLDPM). It is described in the project deliverable D5.5. [13]

Similar to the EU-SysFlex project, the CoordiNet project defined the information exchange requirements for communication between the DSO and TSO. The project aims to improve the CoordiNet profiles based on IEC standards: Common Grid Model Exchange Specification (CGMES), based on IEC 61970 and IEC 61968 and CIM European Style Market profile based on IEC 62325. This is described in deliverable D2.4. [9]

3.3.4 Communication Protocols

Protocols are mechanisms for communication between different technological systems. The involvement of the consumer is often related to the required operations for retrieving and setting data in consumer owned devices (i.e., Smart readers, IoT equipment, Advanced Metering Infrastructure (AMI), etc.) or systems (i.e., platforms for consumer interaction). In the following, some widely used protocols are introduced before the analysis of applied protocols for the data exchange with the consumer is introduced in Table 2.

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- RESTful HTTP

RESTful HTTP describes an architecture style which uses the HTTP protocol for communication that enables interaction between systems and system components. It is the acronym for Representational State Transfer, and it enables API calls.

Within the scope of the selected projects, REST APIs were used for communication between pilots and devices and also to enable interoperability between systems, both within and outside systems.

- SML

Smart Message Language protocol is a communication protocol for Automated Meter Reading, and it's an application layer protocol primary developed for electricity meters. [21] It allows the usage of TCP, HTTP and FTP for data transport.

It was used by the Flex4Grid projects for enabling syntactic interoperability with smart meter readers.

- IMAP and SMTP

IMAP and SMTP are two different protocols, both used for electronic mail transmission. These are widely used in the web across all sectors. In the case of past projects these are used for exchanging data between AMIs.

The protocols applied in the reviewed projects are listed in the following:

Table 2 Protocols used for data exchange with the consumer

Project	Protocols	Standard/Proprietary
EU-SysFlex (Flexibility Platform demo)	HTPP, REST, TLS	
Platone **Empower**	**Web services, FTP, TCP-IP**IEC 60870-5-101 (IEC101), IEC 60870-5-104 (IEC 104), Modbus, DNP3 (Distributed Network Protocol) DEMQTT, HTTP, TCP	SCADA and SESP: in order to establish communication between the SCADA system and SESP system, Web services or FTP have been established Meter and data concentrator through wireless radio frequency; Data concentrator and Head End System through TCP-IP communication; Head end system and SESP through web services using some APIs

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		Home prosumers and SESP: these will be connected either directly from the local controller to the SESP system via TCP-IP, or else by the smart meter
Flex4Grid	RESTful, HTTP (RFC2616-2014) and MQTT, **FTP** (MQTT-2014), Smart Message Language (SML)	standard
Coordinet	HTTP, CIM, 6185	standard

3.3.5 Data Exchange Formats

The reviewed UC applied mostly standard data exchange formats. Here, JSON and XML were largely identified as part of the mechanisms for data exchange as common data exchange formats. These formats can be used on top of the mentioned protocols, for example for carrying the data on the defined API calls.

JSON stands for JavaScript Object Notation, a lightweight data format and easy for humans to read and understand. It was used by Flex4Grid to serialize all internal message payloads.

XML, or Extensible Markup Language, was used in project TDX-Assist for data retrieving from the smart meters.

Table 3 Formats used for data exchange with the consumer

Project	Data exchange formats	Standard/Proprietary
EU-SysFlex (Flexibility Platform demo)	XML	standard
EMPOWER **Platone IT**	JSON, XML	standard
Flex4Grid Platone DE	JSON, XML	standard

3.3.6 Standards

Standards were deployed in the projects CoordiNet and Empower:

Table 4 Applied standards for data exchange with the consumer

Standard	Project	Use Case
IEC 61850	Coordinet	This standard was one of the multiples addressed within the

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		CoordinetN project to be used by the TSOs, DSOs and market participants to help them implement new interfaces.
IEC 60870-5-101	Empower	A review of the IEC 60870-5-101 was made in the Empower project.

IEC 61850 describes a general exchange protocol for intelligent electronic devices at automated electrical substations of Medium Voltage (MV) / High Voltage (HV) networks. It addresses the communication of information for control, supervision, measurement and security at the substation. To achieve interoperability between field devices, the series sets general specifications for the substation, its devices, and its functions, and defines a hierarchical data model as well as a digital interface for the primary data. (IEC TC57, IEC 61850 – Communication Networks and Systems in Substations. 2016)

IEC 60870-5-101 is a standard for power system monitoring, control & associated communications for remote control, remote protection, and associated telecommunications for electric power systems. This is completely compatible with IEC 60870-5-1 to IEC 60870-5-5 standards and uses a standard asynchronous serial tele-control channel interface between DTE and DCE. The standard is suitable for multiple configurations like point-to-point, star, etc. [18]

These standards are not directly related to consumer interaction or flexibility services provision, however, they are key elements for the power system. They tackle communication between substations in the High Voltage and Medium Voltage networks, and management of power systems.

3.3.7 Tools

To achieve effective consumer participation in the flexibility markets, the design of specific consumer tools is critical. For example, consumers equipped with PV systems and with HEMS can manage the energy inside their facilities and they may want to participate in the electric markets using their resources. Besides, grid operators or aggregators can send signals to consumers to participate in demand response programs. On the other hand, access to consumers' data is useful to achieve the effectiveness and efficiency of existing market activities, creation of new services and fulfilling consumers' expectations. In the same time, consumers' satisfaction is improved because they can benefit from data-driven services to obtain additional revenue, to gain control over their data or to contribute to environmental goals. Some digital tools are developed to support consumer participation in the market and to interact with grid operators, aggregators and market players. Hence, this section provides an analysis of the tools used in the reviewed projects for interaction with the consumer or aggregator. This analysis takes into consideration the following aspects:

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- Privacy and data protection
- Access to data
- Cybersecurity
- Algorithms, automated decision-making and artificial intelligence

Table 5 Consumer-centric tools applied in the reviewed H2020 projects illustrates the results from the UC analysis regarding consumer-specific tools for data exchange.

Table 5 Consumer-centric tools applied in the reviewed H2020 projects

Project	Tools
EU-SysFlex (Flexibility Platform demo)	Flexibility Platform (FP) for System Operators and Flexibility Service Providers that enables the trading of different flexibility products and services. A FP is operated by a Market Operator. Available to System Operators and Flexibility Services Providers. It is used to support the prequalification, the bidding, the activation and the verification processes, ensuring coordination between activities undertaken by several operators using the same flexible resources. Several national and regional FPs may exist. Existing Elering's Data Exchange Platform (DEP) is used. Further data services were developed to enable secure exchange of different types of data – e.g. flexibility bids, activation requests, etc. DEP is a communication platform the basic functionality of which is to secure data transfer (routing) from data providers (e.g. data hubs, flexibility service providers, TSOs, DSOs) to the data users (e.g. TSOs, DSOs, consumers, suppliers, energy service providers). DEP stores data related to its services (e.g. cryptographic hash of the data requested). The DEP does not store core energy data (e.g. meter data, grid data, market data) while these data can be stored by data hubs. Several DEPs may exist in different countries and inside one country.
EMPOWER	SESP (Smart Energy Service Provider) The SESP Control Cloud will be based entirely on Microsoft Azure cloud services, where Azure Machine Learning (ML) will act as the brain of the modern smart grid. The IT architecture used for the EMPOWER SESP system is based on Microsoft Azure cloud computing big data PaaS solutions. SESP Control Cloud collects data from virtually any type of meter or sensor. It then runs predictive models in Azure ML to forecast potential capacity problems and automatically control load to the loads in buildings or other infrastructure to prevent outages. The solution provides a short-term 24-hour forecast, a long-term monthly forecast, and a temperature forecast, and it offers a centralized way to monitor and manage the entire grid. "SESP Control Cloud must supports integration towards multiple systems and data sources, such as Smart meters (values, events, etc.), Customer Information System (CIS), Network Information System (NIS), Weather data and Social Media. Standard message formats, such as XML, CIM and GS2 are supported, and the most used integration methods are: Microsoft Azure Event Hub (HTTPS), Microsoft Azure Service Bus Queue (HTTPS) and Web Services (SOAP, RESTful). Key features for SESP Control Cloud: Real time dashboards Automated & customizable processes & workflows ESRI-based GIS-platform with real time data visualization 2-way communication with meter infrastructure Event & alarm handling Customer alerts Real-time customer compensation visualization

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	Outage handling per individual customer Remote opening and closing of meters Tap into data sources which have been off limits Information model built on CIM standards Built on eSmart's big data analytics system platform
Flex4Grid	Local gateway DMS (Distribution Management System) interface Prosumer Cloud Service End-user interface (EUI Data analytics Flexibility Operator interface Flexibility Aggregation Service Security and Privacy Services Prosumer Cloud Service is a collection of components performing a service for the users (prosumers) of the system. The service performed the following tasks: Listened to local gateways real time data traffic and stored the data in the database; Provided a backend for DMS interface so the DSO system data was available for the prosumers and data analytic service; Provided a backend for DSO interface by storing network technical and topological household information; Provided the backend for End user Interface and the local gateway, binding the information about them in a unified picture; Provided in part: Models realized with an authentication service for system users and services and access control service for access to stored information. Stores access control policies, Artificial Neural Network (ANN) model. It provided access decision point and part of system decision enforcement capabilities. The role of the Data Analytics is processing of the consumption data and area consumption peak -prediction. The data analytic elements and peak-event result analyses services. It utilized information about historical power loads and weather forecasts to provide the following functionality in the system: Mechanisms for unification of data from various data sources (household, DMS system), Algorithms for data aggregation and basic data statistics provisioning, REST interfaces to access the data, statistics and aggregates, Mechanisms for 209 ELE electrical substations DMS data collection, storage and features extraction, Mechanisms for collection, storage and features extraction from meteorological parameters predictions (temperature, radiation, precipitation), Mechanisms for training, building and storing for the overall consumption in the next few days. For each day the prediction models Algorithms for daily peak prediction, two days in advance forecast Algorithms for evaluation of past predictions, both of the peak and meteorological parameters Interface for visualization of the predictions and evaluations for Flexibility Operator Interface and Third-Party interface time

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3.4 TSO-DSO-consumer interoperability

The TSO-DSO and consumer interoperability is a key topic in the operation of the electricity market and is even more crucial now as the clean energy transition seems to already affect the energy market globally. Effective coordination between TSOs, DSOs and consumers, in both real-time operation and operational planning, becomes increasingly important to ensure cost-efficient, sustainable and reliable system operation and to facilitate markets throughout Europe.

One good example that shows the benefits of coordination between TSOs, DSOs and consumers is the Interoperable pan-European Grid Services Architecture (IEGSA) of the INTERRFACE project [19]. This open architecture for sharing data among all participants in the electricity system value chain (consumers, grids, market), from local, regional to EU level will enable TSOs, DSOs and consumers to coordinate their efforts to maximize the potential of distributed energy resources (DERs), demand aggregators and grid assets, in a cost-efficient way and create consumer benefits.

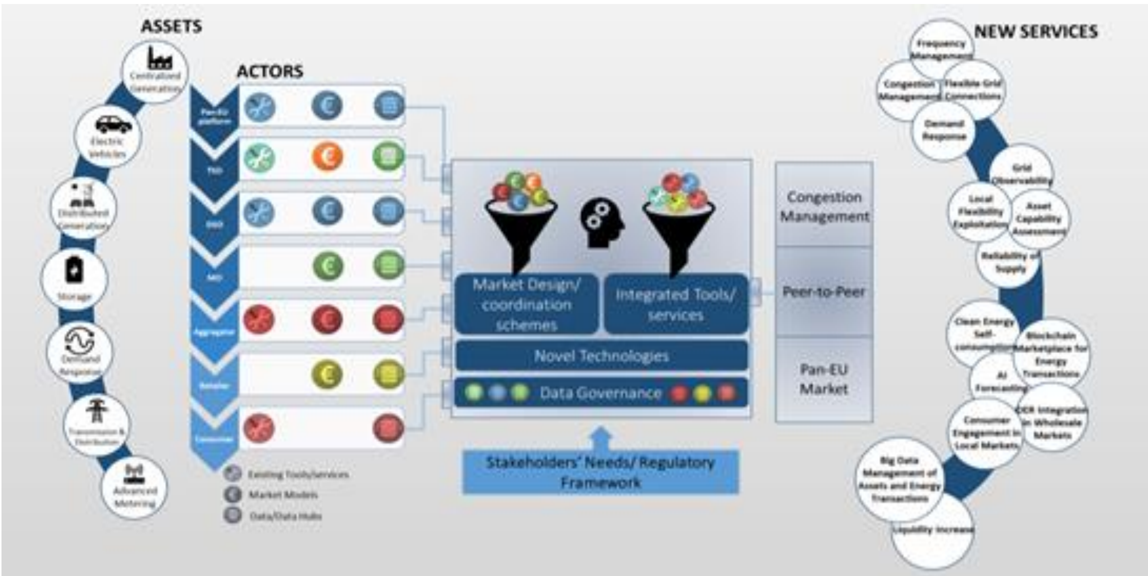

Figure 3-11 - Interoperable pan-European Grid Services Architecture [1]

In this section, the results of the comprehensive analysis are presented, which goes beyond the individual perspective of each actor and aims to include all actors, improve the interoperability and complete the big picture from the point of view of the system. First, the UC reviewed from different perspectives are consolidated to review the actor-specific aspects and draw conclusions for interoperability. Then, the results from the GRIFOn

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forum are presented, which reflect the discussion with European stakeholders and experts from TSO, DSO, industry and academia.

3.4.1 UC consolidation

As all three tasks T4.1, T4.2 and T4.3 have a different focus, TSO, DSO and consumer, respectively, the reviewed projects and UC differ per task. There were two projects, which were reviewed by all three tasks, EUSysFlex and Coordinet. Therefore, first the TS-DSO-consumer interoperability is discussed based on the gaps identified for these two projects from the three perspectives. In order to complete the analysis and provide a more profound view of the system-level issues and interoperability potential, all identified gaps were related to the system level.

The results from the discussion on interoperability aspects and system perspective regarding the projects Coordinet and Platone, as well as general considerations are listed below.

Coordinet

The project is TSO-DSO focused, and the communication with the consumer was mainly performed via manual activation, ad-hoc development

- No standard solutions
- If standards were used, this was coordinated only at UC level or at country level, no coordination across the project
- Challenge for the consumer:
  - big units are supported better, standards are used
  - the participation of small FSPs is costly to the system
  - No real market participation
- Balancing and common congestion management market requires expensive and troublesome communication, therefore it is not possible for aggregators to communicate reliably with the FSPs and flexibility potential is wasted
- Variety among UC, no homogenous solution across countries
  - Problem: EU-wide solutions are ad-hoc with no standard way, which is a barrier to move across countries and extend business models to new countries, which leads to market access limitation
- TSO services require advanced communication which is a barrier to small FSPs
- For local markets at DSO level requirements can be relaxed, different data models and protocols can be used
- Open question to be investigated further:

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- To what extent is this a barrier to small FSPs to participate at the market, as this is connected to additional costs?
- How can we make small FSPs more compatible with small FSPs?
- In how far is the variety of communication models a barrier for consumer integration?

Platone

- Achievement for interoperability: all data from the network was made available and accessible for all; however, in general, the data exchange is a barrier, as the only way is to connect to the Platone interface (MQTT, RESTAPI) without a standard model available
- Project was focused on the DSO perspective, consumer only indirectly through DSO, TSO was not involved. Involvement of all actors would have improved the outcome of the project
- The consumer could participate through an aggregator
- The settlement phase is crucial for the system, and it should be standardized in terms of processes and regulations
- Data management should be done in an automated way

General

- A common CIM model is needed for TSO, DSO and consumer; the DSO side is required to map better data exchange
- There is a variety of options for data exchange, which is a burden to interoperability, as they are often not compatible
- The communication requirements for more demanding products represent a barrier for small FSPs to access the market
- Aggregators focus mainly on industrial flexibility, very limited number of aggregators work with residential consumers - enabling market access for residential FSP would increase the available flexibility for the system and would benefit the system
- Projects often do not include all actors, which affects the quality of the developed solutions
- The global data availability should be improved, e.g. load forecasts of the aggregator could be used at DSO and TSO level
- CIM should be extended to adopt the aspects relevant for smaller DER and synchronized operation
- Further standardization of the bid selection is necessary
- Flexibility of services should be improved
- Standardization of the consent management is necessary, there are no CIM profiles available. TSO and DSO are flexibility byers and might need consent from the consumer to access their flexibility, in case this is not regulated by law

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- Communication requirements for more demanding products are a barrier for small FSPs
- Limited aggregation services for consumers, aggregators focus on industrial flexibility
- Enabling market access for small FSPs would be beneficial for the system
- Projects and initiatives should involve all actors to include all perspectives and work towards solutions beneficial for the whole system

3.4.2 GRIFOn

As already introduced in section 2.7, a special GRIFOn event was organized to involve external experts and discuss the topics of TSO-DSO-consumer interoperability. This section presents the structure of the groups and the results of the discussions.

For each task, three discussion groups with three topics each were foreseen. Each discussion group was moderated by a Onenet partner, involved in the work of the corresponding task. Due to the distribution of participants, only two of the planned three discussion groups for task 4.3 regarding the consumer perspective took place. The results were kept in a miro board and are publicly available. [20]

Group 1

- Q1.1: Which are the three most important barriers in terms of data exchange among consumer and market? How can they be addressed?
  - **Interfaces and data exchange**
    - Interfaces are not unified
    - Limited interoperability among different manufacturers (communication protocols, data structure)
    - Closed IT environment and/or solutions
    - Proprietary data models and communication protocols
      - **Suggestion: Widely adopted open standards**
  - **Architecture and consumer integration**
    - Solutions are not inclusive: not all consumers can join all solutions
    - Approximately 2% of the Dutch smart meter population is not working due to technical problems such as failing GPRS data connection
      - **Suggestion: Rethink the architecture**
  - **Data access (technical, regulatory dimensions)**

- Lack of consent mechanisms for third party data sharing
- Lack of communication mechanisms and interfaces
- Missing standards and data models to enable communication
    - **Suggestion: extend standardization continuously**

- **Regulations and privacy**
    - Lack of knowledge of consumers about market
        - **Suggestion: Intermediate connection to the market**
    - Lack of regulatory framework for data access of third parties
    - The use of data should be in the commercial domain, the solution is in the hands of TSO and DSO. The Authority for Consumers and Markets (ACM) in the Netherlands claims, that they aim to ensure fair competition between business and they want to protect consumer interests; availability of smart meter data serves the interest of prosumers
        - **Suggestion: re-evaluate regulatory approach**

- Q1.2: Which are the three most important barriers in terms of data exchange among consumer and DSO? How can they be addressed?
    - 'Energy Suppliers Model' (leveranciers-model) in the Netherlands
    - This means that one receives one bill for the energy costs, in which both the network management costs and the delivery costs are processed, and consumer pays both to the business energy supplier
    - **Conclusion: single point of contact and better coordination; uniform solutions between supplier and DSO (access smart meter data via supplier vs DSO website)**

    - Consumer data are mainly used for billing purposes
    - **Conclusion: solutions expected from the interoperability acts, first on data sharing and general on the approach**

    - functionalities of the meters, overall smart meter environment
    - **Conclusion: data exchange is mainly one way (customer → DSO)**

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  - set up of data management model in some countries is not complete (e.g. data hubs in the Nordic demos, not established yet in all countries)
  - **Conclusion: accelerate the process of implementation**

  - Smart meter rollout is lagging behind (Germany)
  - Regulatory frame, communication campaigns
  - **Conclusion: resistance to smart meter roll-out**

  - Unclear cost distribution in the light of new services, i.e. demand-side flexibility
  - **Conclusion: regulatory issues with clear cost distribution, as well as financing and ownership of devices that are needed to reach climate goals**

- Q1.3: Which are the most important technical or legal gaps related to Cyber-security?

  The question was not further discussed due to time limitations.

Group 2

Group 2 did not take place, as there were not enough participants who signed up for this group

Group 3

- Q3.1: Which are the data models and ontologies most used in the interaction with the consumer or flexibility provider? Which gaps and barriers are there?
  - CIM data model for large FSP
  - Internally developed data models
  - OpenADR
  - SAREF
  - In the US: Green Button used for sharing consumer AMI data
  - EEBUS: open, two-way information model designed to facilitate information exchange primarily in-home but also with external stakeholders
  - **Conclusion: quite diverse, including tailor-made and/or vendor-specific and/or not open source. This is what makes it challenging for interoperability**
  - Barriers:

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- FSPs capacity to interact with certain systems due to complexity
- individual restrictions per locations
- TSO strict data requirements
- Opportunity for an operator of data as a service for consumers so that other parties can offer services based on the data - flexibility markets, diagnostics, equipment performance, etc.
- Interoperability with in-house system of FSPs (or aggregators)

- General:
  - Custom web-based models for each vendor/aggregator
  - Challenge: different technologies to interact with consumers
  - Individual approach to each consumer (big units)

- Q3.2: Which actions can support interoperability? Standardization, legal actions, cyber-security, AI?
  - Common data model for consumer systems like CIM - data model would be defined for each potential resource (storage, smart inverter, electric vehicle charger, heat pump, water heater, etc.)
  - European energy data space
  - Reference framework/model, to which each model used in real life could be mapped to
  - Clear unified data structure for TSO/DSO connected flexibility units
  - EU network Code
  - Data interoperability implementing acts
  - Data model should incorporate security and privacy elements
  - Ensuring the implementation of the principle of easy access to data and sharing of data by consumers/data owners.
  - Cybersecurity is an increasing concern and needed
  - Arguments beyond the scope of the question
    - Blockchain approaches for registration of resources for a variety of use cases

- Q3.3: Where do you see the most growth in security threats?
  - As it is more and more about private data (personal, commercial), strong rules and tools for privacy respecting need to be in place
  - While amounts of data are increasing drastically, avoid setting up large data warehouses (data hubs, flexibility registers!)
  - Clear split between regulated in commercial domain needed - also from data management perspective
  - Control of widespread consumer devices (IoT)

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- Decentralized and communities requirements? Less strict requirements?
- Further arguments outside the scope of the question to consider
  - Consumer consumption data can make it easy to determine households away for holidays
  - Connection between aggregators and TSO/DSOs should be max secure
  - Consumer data that could reveal personal information and status

4 OneNet Demo UC

To facilitate the identification of relevant components for the guidelines for TSO-DSO-consumer integration, this section focuses on the evaluation of the communication processes between consumers and other roles in the market in the different demos included in OneNet. To develop this analysis, this section presents the results of applying the methodology discussed in Section 2.3 to the different demonstrators in OneNet. For each one of these demonstrators, the different business cases were evaluated to, in close liaison with the teams working in the different demonstrators, identifying the main interactions between the consumers (referred as Flexibility Services Providers or FSPs) and the other agents in the market.

This section starts by identifying the interfaces that demonstrators are using to facilitate the interoperability between agents. Then, the main technical characteristics of these interfaces are discussed with the objective of being able to identify relevant lessons learnt/gaps to input into the guidelines being developed in this document.

The BUCs of the Portuguese demo were not considered in the analysis since their goal is to understand what information should be exchanged and rules should be established between the TSO and DSO to procure congestion management products in the short-term and long-term and to improve the operational planning (facilitate long-term to short-term operational planning for both networks). Those BUCs do not aim to establish and test solutions in the field for data exchange with FSP.

The BUCs of the Spanish demo included interfaces between SOs and FSPs. However, in this demo communication will be undertaken using ad hoc mechanisms. Therefore, no formal data model or communication protocols have been identified. These standards would be considered, if necessary, in further implementations of the results of the project.

4.1 Interfaces and data exchange

When interacting with each other, actors will need to develop interfaces that facilitate the exchange of relevant information. This section identifies and describes the interfaces being developed by the different demonstrators for the interaction with FSPs and its technical characteristics.

4.1.1 Interfaces

Interfaces allow for the transmission of information between the different roles. This section describes the interfaces for each one of the demos in OneNet. The information in these sections has been obtained by reviewing the documentation referring to the use cases being put forward by each one of these demos in coordination with the teams of each one of the demos to ensure an updated vision of their work.

Each of the tables presents the different interfaces for each one of the demos. These interfaces have been divided in function of the roles interacting with the FSP. However, this does not preclude that these interfaces could be combined into one single point of contact to facilitate the interaction between FSPs and the market.

Table 6: Interfaces for the Northern Demonstrators

UC	Interfaces (Name and Description)	Roles
NOCL - 01	FSP-FRO interface – This interface transfer information between these two actors. This information will be used in the following services: • Sending flexibility contracts • Register as FSP in flexibility register • Publish the results of pre-qualification • Confirm/reject resource registration • Update existing resource information • Publish the availability of flexibility resources • Receive product/consumption plans • Receive real-time metering data • Inform about under or overdelivered flexibilities in real-time • Communicate verification results to entitled parties • Forward adjusted volumes to imbalance settlement • Receive and confirm/reject flexibility contract termination requests	FSP, FRO, Imbalance settlement responsible
	FSP-MO interface – This interface transfer information between these two actors. This information will be used in the following services: • Inform about flexibility call for tenders opening • Submit a flexibility bids; • FSP register to secondary market; • Publish the secondary trade; • Send market outcome; • Forward/Receive activation request confirmation.	FSP and MO

Table 7: Interfaces for the UC1 in Cyprus demonstrator – Scenario 1

UC	Interfaces (Name and Description)	Roles
SOCL-CY01 Active Power #Scen. 1 Frequency Disturbance	FSP (Distr.) – (TSO/DSO) Market: This interface will connect FSPs connected to the distribution network to the market. The actions will include: • FSPs in Distribution send availability bids for frequency balancing products	FSP, MO, (OneNet)

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	• Market sends the awarded activation bids for frequency balancing to the FSPs in distribution	
	FSP (Trans.) - (TSO/DSO) Market: This interface will connect FSPs connected to the transmission network to the market. The actions will include: • FSP's in Transmission send activation bids for frequency balancing products • Market sends the awarded activation bids for frequency balancing to the FSPs in transmission	FSP, MO, (OneNet)
	TSO/DSO – FSP: Automatic Activation of FSP's in Distribution for frequency support	TSO/DSO, FSP
	TSO/DSO – FSP: Automatic Activation of FSP's in Transmission for frequency support	TSO/DSO, FSP

Table 8: Interfaces for the UC1 in Cyprus demonstrator – Scenario 2

UC	Interfaces (Name and Description)	Roles
SOCL-CY-01 Active Power #Scen. 2: Overloading conditions (congestion management)	FSP – Local Market: FSPs in Distribution send availability bids for congestion management products	FSPs (Distr.), local market (DSO), (OneNet)
	DSO – FSP: DSO sends the activation orders to FSPs (in distribution)	DSO, FSPs (distr.), (OneNet)
	DSO – FSP: In case of a congestion event, the DSO (through its Active Balancing Congestion Management platform) coordinates the FSPs	DSO, FSPs (distr.)

Table 9: Interfaces for the UC2 in Cyprus demonstrator

UC	Interfaces (Name and Description)	Roles
SOCL-CY-02 Re-active Power Flexibility and Power Quality	FSP – Local Market: FSPs in Distribution send availability bids for reactive power (Congestion Management) products,	FSPs (Distr.), local market (DSO), (OneNet)
	DSO – FSP: DSO sends the activation orders to FSPs (in distribution)	DSO, FSPs (distr.), (OneNet)
	DSO – FSP: In case of a congestion event, the DSO (through its Active Balancing Congestion Management platform) coordinates the FSPs	DSO, FSPs (distr.)

Table 10: Interfaces for the UC1 in the Greek demonstrator

UC	Interfaces (Name and Description)	Roles
SOCL-GR-01 Enhanced	MO – FSP: The interactions between MO and FSP using this interface take place at different points in the market. Forecasting phase	MO, FSP

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Enhanced Active/Reactive Power Management for TSO-DSO coordination	• Send information on identified potential flexibility sources • Confirm the reception of the information Prequalification phase: • Send prequalification requirements • Send the fulfilled list of prequalification requirements • Send request for additional information • Send additional information • Send information on the decision of registration Market phase: • Send information on required amount of flexibility • Send Capacity Bids • Send request for modification of Bids • Send modified bids • Send information on the decision of the bids	
	(Monitoring & Activation phase) TSO/DSO – FSP: During the monitoring and activation phase, this interface will: • Send information on services to be provided • Send report on the provision of the services	TSO/DSO, FSP

Table 11: Interfaces for the UC2 in the Greek demonstrator

UC	Interfaces (Name and Description)	Roles
SOCL-GR-02 Enhanced severe weather condition management and outage management for TSO, DSO and micro grid operator	MO – FSP: This interface will: • Forward Critical Information on Weather Forecast to FSP • Confirm the reception of the critical information	MO, FSP

Table 12: Interfaces for the UC1 in the Spanish demonstrator

UC	Interfaces (Name and Description)	Roles

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WECL-ES-01 Long-term congestion management (Prequalification phase)	FSP - IMO . The FSP requests to the IMO to be pre-qualified to offer a certain type of product exchanging basic participant information, market participant pre-qualification information, market resource pre-qualification information, technical resource pre-qualification information. Once the FSP is notified for incomplete information provided, it reports back missing data to IMO. Once the process is finalized, the FSP is communicated on the successful pre-qualification. If the technical validation is unsuccessful, the FSP is communicated about it. IMO 6 – FSP. Once the process is finalized, the FSP is communicated on the successful pre-qualification. If the technical validation is unsuccessful, the FSP is communicated about it.	FSP, IMO
	FSP – DSO. In the second part of the prequalification phase, the FSP acknowledges the technical validation need providing it back to the DSO.	FSP, DSO
WECL-ES-01 Long-term congestion management (Market phase)	MP – FSP In the market phase Market Platform notifies the FSP about a market opening Qualified FSPs may bid to the market session as long as market session is open (before the Gate Closer Time [GCT]). When the process is finalized, market platform notifies the GCT.	FSP, MP
WECL-ES-01 Long-term congestion management (Monitoring and Activation phase)	FSP- DER. In the monitoring and activation phase, if the state is within normal conditions, the FSP proceeds with the activation in real-time according to the market results.	FSP, DER
	IMO – FSP. This phase ends with the IMO that notifies the FSP on the final settlement.	FSP, IMO

Table 13: Interfaces for the UC2 in the Spanish demonstrator

UC	Interfaces (Name and Description)	Roles
WECL-ES-02 - Short-term congestion management (Prequalification phase)	FSP - IMO. The FSP requests to the IMO to be pre-qualified to offer a certain type of product exchanging basic participant information, market participant pre-qualification information, market resource pre-qualification information, technical resource pre-qualification information. Once the FSP is notified for incomplete information provided, it reports back missing data to IMO. Once the process is finalized, the FSP is communicated on the successful pre-qualification If the technical validation is unsuccessful, the FSP is communicated about it.	FSP, IMO
	FSP – DSO. The FSP acknowledges the technical validation need providing it back to the DSO.	FSP, DSO
WECL-ES-02 - Short-term congestion management (Market phase)	MP – FSP. In the market phase Market Platform notifies the FSP about a market opening. Then, in the second phase, qualified FSPs may bid to the market session as long as market session is open (before the Gate Closer Time [GCT]). At the end, market platform notifies the GCT.	MP, FSP
WECL-ES-02 - Short-term congestion management (Measurement phase)	IMO– FSP. This phase ends with the IMO that notifies the FSP on the final settlement.	FSP, IMO
WECL-ES-02 - Short-term congestion management (Monitoring and Activation phase)	FSP- DER. In the monitoring and activation phase, if the state is within normal conditions, the FSP proceeds with the activation in real-time according to the market results.	FSP, DER

Table 14: Interfaces for the UC2 in the French demonstrator

UC	Interfaces (Name and Description)	Roles
WECL-FR-01 Improved monitoring of flexibility for congestion management	TSO-STAR-FSP, DSO-STAR-FSP, DSO-FSP. All data exchanges are performed and registered in the STAR (System for Trackability of Renewable Activations). • FSP-STAR platform: FSPs who participate in the market should provide day-ahead their flexibility offers and production forecasts (capacity time series, price and forecasting in power time series)	FSP, DSO, TSO, STAR (data exchange platform)

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	• TSO-STAR-FSP / TSO-STAR-DSO-FSP: All activation or deactivation orders are tracked on the STAR platform.
	    ○ The TSO can send a limitation order to the DSO or directly to the FSP if it is connected to the TSO's network.
	    ○ Once congestion is solved, the TSO sends the order to end the flexibility activation.
	    ○ When the DSO receives the TSO's request, it will acknowledge it on the STAR platform and it can send orders or sub-orders to the relevant producers (FSP).
	    ○ Order reception and order execution are tracked through the STAR platform once the FSP has received and executed the DSO's activation. The same is done once the FSP has received the DSO's deactivation order and has performed it.
	    ○ A similar process is followed when the DSO needs to activate the flexibility provided by the FSPs connected to its grid to solve congestion in the distribution grid.	

Table 15: Interfaces for UC1 and UC2 in the Czech Demonstrator

UC	Interfaces (Name and Description)	Roles
EACL-CZ Reactive power overflow management & Voltage Control	FSP-P interface - This interface transfers information between the Flexibility Service Provider and the Market Exchange Platform. It is used in the following services: • Evidence of flexibility demands • Evidence of bids • Evaluation of bids • Traffic light mechanism • Unit Preparation	FSP, P

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Table 16: Interfaces for UC1 in the Hungarian Demonstrator

UC	Interfaces (Name and Description)	Roles
EACL-HU MV feeder voltage control	MO-FSP-DSO interface - This interface transfers information between the Market Operator, Flexibility Service Provider and the Distribution System Operator. It is used in the following services: • Prequalification Request • Approval of prequalification • Prequalification Results • Submitting bids	FSP, DSO, MO

Table 17: Interfaces for UC1 in the Slovenian Demonstrator

UC	Interfaces (Name and Description)	Roles
EACL-SI Voltage Control in distribution grid	FSP-P-DSO interface - This interface transfers information between the Flexibility Service Provider, Market Platform and the Distribution System Operator. It is used in the following services: • Prequalification • Flexibility Request • Acknowledgement • Activation • Traffic Light mechanism • Settlement	FSP, DSO, MO

4.1.2 Data models

To facilitate the interoperability between the devices operated by the different roles, it is important that there is clarity, and to a certain degree, harmonization between the approaches to data organisation and management. Therefore, when developing an interface, it will be important to consider the data model to be used where a data model is an abstract model that organises elements of data and standardises how they relate to one another and to the properties of real-world entities. [8] This section presents the data models being used by each one of the demonstrators.

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Table 18: Data Models for the Northern demonstrators

UC	Standards and data model
NOCL - 01	FSP – FRO interface –Proprietary
	FSP – MO interface – specific to the MO: FSP – Nordpool – Proprietary FSP – Piclo – Proprietary FSP – Elering – ERRP (ENTSO-E's Reserve Resource process) FSP – Fingrid – ERRP but transitioning to CIM FSP – AST – CIM FSP – Litgrid – Proprietary and CIM FSP – ESO – CIM

Table 19: Data Models for the Cyprus demonstrator

UC	Standards and data model
SOCL-CY – 01 **Active Power**	Tailored proprietary Data Model
SOCL-CY-02 **Re-active Power Flexibility and Power Quality**	Tailored proprietary Data Model

Table 20: Data Models for the Greek demonstrator

UC	Standards and data model
SOCL-GR-01 **Enhanced Active/Reactive Power Management for TSO-DSO coordination**	CGM (/ IGM) Tailored proprietary Data Model
SOCL-GR-02 **Enhanced severe weather condition management and outage management for TSO, DSO and micro grid operator**	Tailored proprietary Data Model

Table 21: Data Models for the French demonstrator

UC	Standards and data model
WECL-FR-01 **Improved monitoring of flexibility for congestion management**	ESMP, ISO8601

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Table 22: Data Models for the Czech demonstrator

UC	Standards and data model
EACL-CZ **Reactive power overflow management and Voltage Control**	CIM with custom extensions

Table 23: Data Models for the Hungarian demonstrator

UC	Standards and data model
EACL-HU **MV feeder voltage control**	Has not been decided yet (potentially proprietary)

Table 24: Data Models for the Slovenian demonstrator

UC	Standards and data model
EACL-SI **Voltage control & Congestion management in LV distribution grid**	CIM with custom extensions

4.1.3 Communication protocols

To facilitate the communication between the different roles, demonstrators need to set communication protocols. These protocols are "system of rules that allow two or more entities of a communications system to transmit information via any kind of variation of a physical quantity. The protocol defines the rules, syntax, semantics and synchronization of communication and possible error recovery methods. Protocols may be implemented by hardware, software, or a combination of both." [4]

This section presents the protocols being proposed by the demonstrators for each one of its interfaces.

Table 25: Protocols for the Northern demonstrators

UC	Protocols
NOCL – 01	FSP – FRO interface – REST
	FSP – MO interface – specific to the MO: FSP – Nordpool – REST FSP – Piclo – REST FSP – Elering – REST POST web service

[4] BRIDGE- data management working group, 2021. "European energy data exchange reference architecture". Available in https://ec.europa.eu/energy/sites/default/files/documents/bridge_wg_data_management_eu_reference_architcture_report_2020-2021.pdf

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	FSP – Fingrid – ECP (ENTSO-E's Energy Communication Platform) FSP – AST – REST FSP – Litgrid – REST or ECP FSP – ESO – REST

Table 26: Protocols for the Cyprus demonstrator

UC	Protocols
SOCL-CY-01 **Active Power**	IEEE C37.118 Ethernet PLC GPRS MQTT
COCL-CY-02 **Re-active Power Flexibility and Power Quality**	Ethernet PLC GPRS MQTT

Table 27: Protocols for the Greek demonstrator

UC	Protocols
SOCL-GR-01 **Enhanced Active/Reactive Power Management for TSO-DSO coordination**	EFI FTP ICCP XMPP
SOCL-GR-02 **Enhanced severe weather condition management and outage management for TSO, DSO and micro grid operator**	

Table 28: Protocols for the Czech demonstrator

UC	Protocols
EACL-CZ **Reactive power overflow management and Voltage Control**	Web services Ethernet ECP AMQP

Table 29: Protocols for the Hungarian demonstrator

UC	Protocols
EACL-HU	Unknown, Not defined yet

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MV feeder voltage control	

Table 30: Protocols for the Slovenian demonstrator

UC	Protocols
EACL-SI **Congestion management and Voltage Control in LV distribution grid**	Ethernet MQTT Web Services AMQP

4.1.4 Data exchange formats

To transfer the information required in the communication protocols, the different demonstrations need to agree a data exchange format or a standard to be used to encode the data. This data forms specifies how bits are used to encode information in a digital storage medium.

The proposed formats for each one of the interfaces are presented in the tables below.

Table 31: Data formats for the northern demonstrators

UC	Data exchange formats
NOCL - 01	FSP – FRO interface –JSON, GUI and proprietary
	FSP – MO interface – specific to the MO: FSP – Nordpool – JSON FSP – Piclo – JSON, GUI and xlsx FSP – Fingrid – XML FSP – AST – XML FSP – ST FSP – Litgrid – XML, xls FSP – ESO – XML, xls and JSON

Table 32: Data formats for the Cyprus demonstrator

UC	Data exchange formats
SOCL-CY-01 **Active Power**	Custom structures (json, csv), in certain cases CIM/ESMP Market profiles
SOCL-CY-02 **Re-active Power Flexibility and Power Quality**	Custom structures (json, csv), in certain cases CIM/ESMP Market profiles

Table 33: Data formats for the Greek demonstrator

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UC	Data exchange formats
SOCL-GR-01 **Enhanced Active/Reactive Power Management for TSO-DSO coordination**	Custom structures (json, csv), partially CIM/ESMP Market profiles
SOCL- GR-02 **Enhanced severe weather condition management and outage management for TSO, DSO and micro grid operator**	Custom structures (json, csv), partially CIM/ESMP Market profiles

Table 34: Data formats for the Spanish demonstrator

UC	Standards and data model
WECL-ES-01 **Long-term congestion management**	Web UI, email, AMI, SCADA
WECL-ES-02 **Short-term congestion management**	Web UI, email, AMI, SCADA, potentially WWSS, AMPQ

Table 35: Data formats for the French demonstrator

UC	Data exchange formats
WECL-FR-01 **Improved monitoring of flexibility for congestion management**	TSO-STAR Platform, DSO-STAR Platform (CSV, registration of FSP) FSP-STAR Platform (JSON, declaration of a unit rate per production site) TSO-STAR platform, DSO-STAR platform (JSON, order registration, estimated curtailed energy, production metering)

UC	Data exchange formats
EACL-CZ **Reactive power overflow management and Voltage control**	CIM XML, ESMP

UC	Data exchange formats
EACL-HU **MV feeder voltage control**	Unknown, Not defined yet

UC	Data exchange formats
EACL-SI **Congestion management and Voltage control in LV distribution grid**	XML, ESMP, JSON

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4.1.5 Tools

The information and data exchanged using the methods above will be used in the development and testing of a number of tools that actors will be able to use as part of the business case they are demonstrating. These tools are summarised in the following tables.

Table 36: Tools for the Northern demonstrators

UC	Tools
NOCL – 01	FSP – FRO interface – Flexibility Register
	FSP – MO interface – specific to the MO: FSP – Nordpool – OneNet Proxy Intraday LTS FSP – Piclo FSP – Elering – BHT (Balance Management System) FSP – Fingrid – Vaksi (Balance Management System) FSP – AST – Custom system for demo FSP – ST FSP – Litgrid – Balance management system FSP – ESO – OneNet system

Table 37: Tools for the Cypriot demonstrators

UC	Tools
SOCL-CY-01 **Active Power**	Active Balancing congestion management (ABCM) platform at the TSO and DSO control centers (ABCM-T and ABCM-D.) Monitoring tools for collecting PMU & SCADA measurements.
SOCL-CY-02 **Re-active Power Flexibility and Power Quality**	Active Balancing congestion management (ABCM) platform at the DSO control center (ABCM-D). Monitoring tools for collecting Smart-Meter & SCADA measurements.

Table 38: Tools for the Greek demonstrators

UC	Tools
SOCL- GR-01 **Enhanced Active/Reactive Power Management for TSO-DSO coordination**	F-Channel (TSO-DSO Flexibility Channel): digital platform that can demonstrate the setting-up of flexibility market with various common products for TSO-DSO coordination. Load forecasting tools (using also weather forecast as input) Production forecasting tools (using also weather forecast as input) Simulation & Analysis Tools for Capacity Forecasting

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SOCL- GR-02 **Enhanced severe weather condition management and outage management for TSO, DSO and micro grid operator**	F-Channel (TSO-DSO Flexibility Channel): digital platform that can demonstrate the setting-up of flexibility market with various common products for TSO-DSO coordination. POI Weather Forecast tools (internal or external service)

Table 39: Tools for the French demonstrators

UC	Tools
WECL-FR-01 **Improved monitoring of flexibility for congestion management**	STAR - System for Trackability of Renewable Activations for Automated. This platform is based on blockchain technology, aims to simplify and optimize the management of renewable production curtailment, by covering the entire life cycle of a flexibility offer, from the formulation of offers to the control of their activations for invoicing. The platform should in particular host and give access to the following information: generators' flexibilities offers, activation orders, metering data.

Table 40: Tools for the Czech demonstrators

UC	Tools
EACL-CZ **Reactive Power overflow management and Voltage Control**	Access Net - Flexibility platform which enables centralized approach, unified communications between stakeholders, is defined on standards, enables a register of providers and provides a possibility to scale-up through modules. It is also based on the ECCo SP standards with automatic messaging, access via ECP endpoint and testing & production environment.

Table 41: Tools for the Hungarian demonstrators

UC	Tools
EACL-HU **MV feeder voltage control**	Hungarian platform - In high level 3 layers should be differentiated: the head-end master platform (platform of platforms), which gives the governance and master data model to all local and regional platforms. Next one is the local platform solution, in our demo this is a Hungarian flexibility platform, which covers the TSO, DSOs, aggregators, large consumers/producers, traders and other stakeholders, and nevertheless small energy 'communities', which can be a regional P2P market, balancing group, etc. The third layer is the end user from platform point of view. The data flow between 2 layers is bilateral, mainly via middleware solution, and there are input data sources, which planned only one direction communication (eg. weather forecast, etc.)

Table 42: Tools for the Slovenian demonstrators

UC	Tools

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EACL-SI **Congestion Management and Voltage Control in LV distribution grid**	Moj Elektro - National portal for consumer and retailers data. Used also for prequalification and registration purposes. Flexibility Server - Solution used for Settlement processes, Registration procedures and FSPs management. ORCA - One of Slovenia's FSPs proprietary solution. Functions as a IoT Platform and a Virtual Power Plant for sending automated activation signals towards active customers. State Estimator - Flexibility platform for Voltage control purposes. Calculates the required flexibility in LV distribution nodes and sends flexibility requests and activation signals towards the Flexibility platform.

The chapter shows that demonstrators are considering different exchanges of information with consumers which can result in different requirements and, as a result, different data models and communication protocols. Furthermore, several of the demonstrators are still using proprietary data models that could make the integration more difficult going forward. Finally, also to flag up that currently data models developed by the sector by CIM do not include the relationship with the consumer, which could require future extensions.

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5 Guidelines for TSO-DSO-consumer interoperability

Interoperability is a key factor for the implementation of the flexibility markets, since it enables data exchange among multiple stakeholders and systems. However, the performed analysis based on the methodology described in Chapter 2 to the UC from the H2020 projects and the OneNet project identified several gaps in the interfaces and data exchange. Therefore, this chapter provides recommendations and implementation requirements based on the gap analysis to provide a plan for the practical solution of the identified gaps.

As a final part of this chapter and central contribution of this deliverable and the work of task 4.3, a set of guidelines is formulated to ensure a reliable data exchange among devices and systems during the operation of flexibility markets, to support TSO-DSO-Consumer interoperability and outline the required steps towards an integrated TSO-DSO-consumer operation.

5.1 Characteristics and properties of the data exchange

The data exchange details were collected from H2020 projects and demo use cases and analysis was based on expert assessment of OneNet partners. The performed analysis of the data exchange provides a clear and comprehensive map of all characteristics and properties of the data used to support interactions between actors, components and systems, including TSO, DSO and consumer. The data exchange details presented in Table 43 were used as an input to define the gap analysis and finalize the corresponding recommendations and implementation requirements.

Table 43 An example of the use case analyzed showing all data exchange details collected

Involved Roles	**A AO**	**AO A**	**AO A**	**TSO A**	**A TSO**	**A DSO**	**DSOMO**	**A MO**	**MO A**
Name of information									
Exchanged Data	Availability of the asset - hours of day - amount	All relevant asset data		Aggregated by BID ID: - hours - volume - price	Active power (-Market ID) -Aggregator's ID -Times -Volumes -Prices	Reactive power demo -Aggregator's ID -Times -Volumes	Reactive power demo - Times -Volumes	Reactive power demo Aggregated: - times - volumes	Reactive power demo Aggregated: - times - volumes

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Data Name	Data Update Request	Asset Data	Data Updated	Accepted Bid	Bid		Reactive Power Needs	Asset Offer	Bid Activation
Data Description	Request from the forecasting tools to update the data related to a specific type of resources or market. It includes: - type of resource ID - time period to forecast	This includes historical and status data for a specific asset or group of aggregated assets. It may include: - Historical data - Status - Planned operations (e.g. planned maintenance, advance booking, etc)	Notification that the data related to a specific asset has been updated.	Bid ID -Times -Prices -Volume	Bid for active or reactive power market. It may include: -Market ID -Aggregator's ID -Times -Volumes -Prices		Needs for reactive power. -ID of a part of the network -time periods -reactive power needed (in kvar) for each time period	Information about the assets and their willingness to provide reactive power for the upcoming time period. -Asset ID -Reactive power that can be provided during the next time period (kvar)	Bid ID -times -volumes
Volume	SMALL	SMALL	VERY SMALL	VERY SMALL	SMALL	VERY SMALL	VERY SMALL	VERY SMALL	VERY SMALL
Frequency	2/DAY	2/DAY	2/DAY	1/DAY	1/DAY, LATEST BEFORE 18:00	1/WEEK	1/WEEK	1/WEEK	1/WEEK
Reliability	LOW	LOW	HIGH	HIGH	HIGH	HIGH	LOW	LOW	LOW
Data Model	Hierarchial			PROPRIETARY	PROPRIETARY	NaN	NaN	NaN	NaN
Communication Protocol	f.ex. REST API*	Asset to paltform used in different sub demos: REST API, Modbus TCP, OCPP, OPC UA		ELCOM	PROPRIETARY	NaN	NaN	NaN	NaN

It is worth noting that for some UC, data exchange details were (partly) missing, therefore, the table represents the state of knowledge for the time being. This was particularly present in the use cases from demos due to ongoing progress in several demos and also missing information on SharePoint.

5.2 Recommendations and implementation requirements

This section builds a bridge between the theoretical UC analysis and identified gaps from previous work and the practical solution of these issues by defining concrete recommendations and implementation requirements as presented in Table 44 and Table 45. According to the focus of the work of task 4.3, the gaps consider solely communication aspects. However, several non-communicational gaps were also identified, which are discussed in the following.

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Several UC do not provide sufficient level of detail regarding information exchange, or at least these are not publicly available. In the case of EU and tax-funded projects, it might be considered essential for (EU) citizens to make such project outcome publicly available for further analysis and research to secure innovation, achieve environmental goals and improve their general living conditions.

Another aspect is that projects very often do not include all actors. The missing perspective and input from one or more actors limits the contribution to interoperability and the opportunities to create a common market.

Furthermore, often consumers are included as passive third parties, but they do not have any control over their data, nor data format or set points.

The review showed that the settlement phase is often not clearly declared, which is a central factor for the realization of flexibility markets.

Table 44 Recommendations and implementation requirements based on the gaps identified in H2020 project UC

Project Name	Gaps listed	Recommendation	Implementation requirement
EU-SysFlex	Consent information sharing processes is not supported by CIM (what kind of data exchange protocols are more useful to base it on?)	Further develop CIM – the importance of private (incl. personal) data is increasing and FSPs, MOs, SOs need consent from the customer, preferably in an harmonised way.	Implement planned data interoperability implementing acts. Update IEC CIM standards and Harmonised Electricity Market Role Model (HEMRM).
Integrid SL	'HEMS' are Industrial RTU which send data to VPP, Information exchange between HEMS and VPP is proprietary	Avoid proprietary solutions as HEMS may want to switch VPPs time-to-time, and VPPs may want to connect to variety of HEMS.	Implement, and if needed, extend IEC CIM standards.
Empower	Need of defining standards for data exchange between SCADA with DERs (storage, load controllers, microgeneration, EVs) or prosumers/consumers appliances. E.g., read data on demand from DER device, send on/off command to DER device, read meter values on	Define the processes, roles, tools, standards and responsibilities for DER-SCADA data exchange.	Update IEC CIM standards to include DER-SCADA data exchange. Use data exchange platforms and/or flexibility registers as intermediaries for data exchange with smaller units.

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Project Name	Gaps listed	Recommendation	Implementation requirement
	demand, charging and discharging EVs.		
Empower	It is not clear how the data anonymization, consent management and personal data management are done. Data anonymization is not explicit in standards.	Enable standard solutions for data anonymisation.	Ensure GDPR implementation by means of anonymisation to avoid leakage of personal data. Consult CIM Expert Group of ENTSO-E to see if IEC CIM standards can contribute to modelling of anonymised data. Implement planned data interoperability implementing acts. Update IEC CIM standards and HEMRM.
Empower	Modbus is an applicative messaging protocol but the definition of the data is free and not standardized.	Use vocabulary and semantics of CIM and HEMRM.	
Flex4Grid, Empower	CIM is not used for data exchange. There are few references to the data models. It is mentioned that DSOs use various management systems and technologies to monitor the health and usage of distribution networks; however, some of them are developed for specific customers and do not yet support standards like CIM and other communication protocols.	Apply standard data models for DSO related data exchanges.	Make proposals to CIM Expert Group of ENTSO-E for extending CIM profiles.
Flex4Grid	The functionality of F4G DMS Interface is to collect end-user energy consumption data and send it to the Prosumer Cloud Service. The energy data and energy transfer data need to be	Clarify the rules and the responsibilities for the energy management platforms	Implement, and if needed, extend IEC CIM standards.

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Project Name	Gaps listed	Recommendation	Implementation requirement
	covered by the standards.		
Flex4Grid	It is recommended that standards address data exchange on real-time and near-real-time measurements and flexibility activation requests.	Apply standard data exchanges for real-time and near-real-time measurements and activation requests.	Implement, and if needed, extend IEC CIM standards.
Platone IT, CoordiNet	The main gap of this use case it is the lack of defined and standard data models. The interfaces are well defined and described and also the communication protocols and security aspects are already identified.	Apply standard data models.	Make proposals to CIM Expert Group of ENTSO-E for extending CIM profiles.
CoordiNet	Variety of options for data exchange for aggregators/FSPs.	Publish-Subscribe technology should be used for real-time market or metering data information exchange, due to the one-to-many relationship and the random timings in the data sources.	Publish-Subscribe technology (MQTT) easy interoperability and reusability of applications
CoordiNet	Communication requirements of more demanding products represent a barrier for small-FSP.	Incentivize aggregation which can handle requirements and for local products lower the requirements to allow small FSP to participate.	Develop aggregators regulation and implement lower communication requirements for local markets, e.g. API REST

Table 45 Recommendations and implementation requirements based on the gaps identified in OneNet demo UC

Project Name	Gaps listed	Recommendation	Implementation requirement
NOCL – 01 **FSP-FRO interface**	The use of proprietary information models would make it more difficult for FSP to participate in different	Incentivise the creation of tools that facilitate the interface with multiple proprietary systems.	Create working groups that help identifying the main characteristics of these systems to facilitate the

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	national markets FROs if FROs are created nationally		development of these communication platforms.
NOCL – 01 **FSP-MO interface**	The existence of multiple information models (or variations of some of REST) would make it more difficult for a FSP to participate in multiple markets. These data models were not developed for the interaction with FSP. Therefore, they can be too complex and they do not include the relevant information for these interactions. Modifications could be required.	Harmonise the information system to facilitate the interoperability between countries. When necessary, extend the data models to cover the requirements from the FSP.	Make proposal to CIM expert group of ENTSO-E for extending CIM profiles. Create working groups that help identifying the main characteristics of these systems to facilitate the development of these communication platforms.
UC WP8_GR Enhanced Active/Reactive Power Management for TSO-DSO coordination **EACL-CZ** **Reactive** power overflow management and Voltage Control **EACL-SI** **Voltage** control & Congestion management in LV distribution grid	Almost all FSP-related information exchange are using objects included (or to be included) in the CIM/ESMP. Certain exchanges (like "request for additional information for pre-qualification") might not be part of CIM [TBC]	Extend CIM for additional FSP-related data exchanges.	Make proposals to CIM Expert Group of ENTSO-E for extending CIM profiles.

5.3 TSO-DSO-consumer interoperability

To take the next step and elevate the discussion from actors' to system perspective and outline guidelines for interoperability, in the following, the individually identified gaps from the analysis of H2020 and OneNet UC

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for each actor's perspective are mapped to the system level to examine the effects and consequences in the background. The results are presented in Table 46.

Table 46 Mapping of level-specific gaps to the system level

Actor	Identified gap	System-level consequence
TSO	Proprietary information model is used. Additional info on used information model and communication protocols may be needed for further analysis.	Using proprietary protocols can be a barrier to deploying the flexibility markets. Interoperability is an important feature in deploying flexibility markets, which requires the definition of standard solutions (as much as possible) for data exchange in order to increase the participation of new players. The adopted data exchange solutions should be developed to impact the implementation decisions of other parties minimally. Conversely to the proprietary solutions, compliance with applicable standards ensures that the data exchange and communication infrastructure can be connected to as many different systems of many stakeholders as possible, enabling the deployment of the flexibility markets. Information models will be key to ensure seamless data exchange between parties in an increasingly digitalised energy sector. The aim is to take into account parameters such as the preparedness of the DSOs to implement the solutions developed, which leads to the fact that some DSOs using customised data models and others alternatively starting to implement Common Information Model (CIM), using customised profiles or the common distribution power system model (CDPSM) profile (IEC 61968-13 2021). On the other hand, information models do not fully cover local market flexibility exchange. For these reasons, DSOs, whenever possible, respect compatibility with the CIM, although this will require further developments, alongside full normalization on data exchange by European responsible bodies.

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TSO	Computation of forecasting for different flexibility needs not covered in standards. It is not possible to identify each data model and communication protocol per each interface.	Due to the variability and uncertainty in the grid operation brought by the renewables-based resources, the forecasting phase is crucial to anticipate the flexibility needs. There is a need for standards to cover data collection in order to develop forecasting tools for different time frames. All these standards needs to cover the different types of needs not only for the TSOs, but also for all DSOs which can be really hard due to the wide variety of sizes of DSOs that exist on a European level.
DSO	Lack of standardization for flexibility services for DSO on the interface / data exchange level. Also unstandardized data exchange protocols and information models on the national level. Lack of coordination on the TSO-DSO level.	Since DSO can procure flexibility services to solve local problems, the adoption of standards solution for data exchange becomes critical for the DSOs to use the DER flexibility. Beyond the definition of standards products for the flexibility services, the data exchange between DSO and other stakeholders requires further developments to deploy local flexibility markets. Adopting the CIM at the distribution side can unlock and facilitate the data exchange between DSO and other stakeholders. However, this standardization may become complex as it will have to take into account the differences that exist from country to country and from DSO to DSO, knowing the great variety of DSOs across Europe. For some DSOs, the adoption and implementation of these standards can become complex because of their small structure.
Consumer	Consent information sharing processes is not supported by CIM	Access to consumer data (e.g., consumption data) could be important for other stakeholders to develop new tools and algorithms related to the flexibility services. However, for that purpose, sharing the consumer consent message is needed, which allows dealing with access permission to the consumer data by another stakeholder. Regarding the Local markets, this point could be critical, since the GDPR is increasingly demanding when it comes to data privacy,

		and in local markets we may be talking about exchanges of personal data.
Consumer	Need of defining standards for data exchange between SCADA with DERs (storage, load controllers, microgeneration, EVs) or prosumers/consumers appliances. E.g., read data on demand from DER device, send on/off command to DER device, read meter values on demand, charging and discharging EVs.	With the decentralization of power systems, mainly to the increased connection of DER to the distribution systems, it becomes necessary to define rules to ensure the communication between small distributed energy resources of prosumers and other consumers, their aggregators and SCADA of grid operators. The development of control architecture solutions and data exchange processes to manage electric grids with large amounts of DERs will be crucial. Otherwise, participation of the DER in providing flexibility to the grid operators will not be effective.
Consumer	It is not clear how the data anonymization is done. Data anonymization is not explicit in standards.	Since the implementation of flexibility markets involves using and sharing data from the consumer, this process must protect sensitive, personal, and confidential data while preserving the data's format and referential integrity.
Consumer	CIM is not used for data exchange. There are few references to data models; however, some of them are developed for specific consumers and do not yet support standards like CIM and other communication protocols.	Once the flexibility procurement involves different phases, CIM extensions and new CIM profiles need to be designed to include different aspects such as prequalification of the flexibility providers, forecasting computation, baseline estimation and bids selection. Such fact leads that some projects do not use CIM as a standardized solution for data exchange in flexibility demonstrators.

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Consumer	The functionality of F4G DMS Interface is to collect end-user energy consumption data and send it to the Prosumer Cloud Service. The energy data and energy transfer data need to be covered by the standards.	Data related to consumption and generation appliances are important to anticipate the flexibility needs and check the effective service provision to the flexibility providers. However, it is required to understand how CIM could cover the central meter data storing or vice-versa, from the data hub to the consumer. Furthermore, this data could be shared with other stakeholders, which demands that those data exchange processes should be transparent and follow standardized solutions (as possible).
Consumer	It is recommended that standards address data exchange on real-time and near-real-time measurements and flexibility activation requests.	The need for real-time or near real-time flexibility is usually associated with the critical operating condition of the electric grids, requiring fast actions to mitigate the technical problems. Sometimes, those events are triggered by faults or misoperation in electric grids. Since prompt actions are needed in those conditions, standardized solutions for data exchange will be important to guarantee that the grid operators can use the flexibility provided by DERs in order to solve the technical issues.
Consumer	Consumers don't have any control on the interaction and data exchange. No information on data format and on setpoint data models.	The access to own data and the capability to share that data are not widely addressed in standards, which can reduce the will of individual consumers to participate in the flexibility markets.

5.4 Conclusions

Data exchange between stakeholders is critical for the deployment of DER's flexibility procurement processes. However, stakeholders need more interoperability to achieve a comprehensive data exchange across the power systems value chain (generation-TSO-DSO-consumption). Indeed, improved interoperability for the data exchange will enable a more efficient grid operation and planning by the TSOs and DSOs, as well as lower barriers to the participation of prosumers and emerging actors in flexible markets. This will facilitate the development of new business models and opportunities for demand and generation flexibility, which also

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contributes to a more active role of the prosumers. Furthermore, the consumer-centric review of sources also showed that it might be necessary to develop a common vocabulary used in projects and initiatives to clearly differentiate between customer and consumer, especially as the EU envisages cross-sector interoperability, and similar terms could have different meaning in different sectors or relationships.

The following principles are usually reported as of the utmost importance in the data exchange:

- Promote the competition in flexibility markets, enabling the entrance of new players and businesses;
- Guarantee transparency of data exchange;
- Develop and set up simple and cost-efficient data exchange solutions;
- Ensure privacy and data security in compliance with the regulation and standards in place;
- Ensure neutral and non-discriminatory access to data and preserve the data quality;
- Deploy the harmonization of data exchange, mainly via the use of standards;

Through the analysis of the UC from previous H2020 projects and from the OneNet project, as well as the insights collected during the GRIFOn session, the following gaps and opportunities for the TSO-DSO-Consumer interoperability have been listed:

- From the analysis of several H2020 projects, one can infer that there are various data exchange options; most of them have been developed in research and development projects. However, opportunities still exist to enhance the standardization of the data exchange processes. For example, some projects have already detected that there are EU-wide solutions without using the standards. Such characteristics do not allow the move of data exchange solutions across countries and extend business models to other countries. Furthermore, there is also reported limited interoperability among different vendors, leading to closed IT solutions' development. The experiences and lessons learned from different H2020 projects and other initiatives should contribute to defining a set of requirements for harmonizing data exchange solutions.
- The aggregation for flexibility services has been mainly focused on industrial loads. The number of aggregators working with residential consumers is small, corresponding to a barrier to market access for residential FSP. Such is a critical aspect for the electrical system to take advantage of the available flexibility provided by the residential sector.
- Another barrier concerns the communication requirements for smart FSPs to connect with other players. The communication requirements to participate in specific flexibility services are quite demanding, which also represents a barrier to the participation of small FSPs.
- From the analysis of H2020 projects, either already finished or under development, one can also notice that some projects do not consider all the roles, mainly the small FSP. This also affects the development of solutions for data exchange among different actors within the electric value chain and, consequently,

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the consumer's participation in the flexibility markets. Besides, this is also a limitation in understanding to what extent the small FSPs can be competitive in providing flexibility services.

- A set of standards has been proposed for data exchange across the electric sector through the common information model (CIM). Several projects have highlighted that CIM has flexibility for proper data sharing, merging, and transformation into reusable information. It represents a common concept of controlling information for systems, applications, networks and services. Along with CIM IEC 61850 is another standard widely used in several projects to define communication between devices in the substation and related system requirements. Nevertheless, it has been pointed out that CIM needs to be extended for the distribution side.
- It is reported that CIM should be extended to adopt the aspects relevant to smaller DER (small FSPs). In particular, it is not widely addressed yet in the standards of the direct DER-SCADA communication between small DER of the prosumers, their aggregators and systems operators' SCADA.
- A relevant aspect of the small FSP participation in the flexibility markets is the right to access own data and the ability to handle personal data. For instance, it is not addressed in the standards how to access meter day by the owners and by third parties through the data owners' consent. Hence, it has been recommended to cover the sharing access permission between data owners, other stakeholders, platforms, applications and data sources. Accordingly, more harmonization is required for the data aggregation and respective anonymization to ensure a secure and transparent data exchange.
- Data from consumers are mainly used for billing purposes. The data exchange interaction is mainly done from the consumers to the DSO. The consumers have difficulty understanding the difference between energy suppliers and DSO, which can be a barrier to deploying the flexibility markets. During the GRIFOn session, it was proposed to establish a single point of contact through better coordination and harmonized solutions between energy suppliers and DSOs. It was also highlighted the definition of the data management model in Europe is not completed, requiring an acceleration of that process, e.g., using data hubs like in Nordic countries.
- On the other hand, the smart meter rollout is lagging in some European countries. Consequently, it is necessary to review the regulatory framework to achieve high integration of smart meters in Europe to get the data that will be required for the different phases of flexibility services procurement.
- Requirements are also necessary for the standards to cover the market baseline calculations, bids selection and forecasting computation.
- Regarding regulatory questions, it becomes important to make clear the distribution costs due to the dissemination of the flexibility services and who pays for devices that are clearly needed to reach the decarbonization targets (e.g., smart meters, HEMS).

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- Among the solutions addressed during the GRIFOn session, the following ones were highlighted: CIM data model for large FSP, OpenADR, SAREF, EEBUS and internally developed data models. Data models and ontologies for interaction with the consumer or flexibility provider are quite diverse, including tailor-made, vendor-made and not open source solutions. This corresponds to a significant barrier to the interoperability of the TSO-DSO consumer.
- Also, during the GRIFOn some actions were proposed to support interoperability as follows:
    - a clear data structure for TSO/DSO connected flexibility units;
    - reinforcing the role of EU network codes to overcome some barriers for FSP, especially small ones;
    - data interoperability implementing acts including security and privacy aspects
    - Ensuring the implementation of the principle of easy access to data and sharing of data by consumers/data owners;
    - defining cybersecurity rules due to the increased decentralization and digitalization of power systems

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7 Appendix I Questionnaire H2020 projects

Questionnaire: Literature review regarding consumer engagement (WP4: T4.3)

Please fill out one questionnaire individually for each demo of the reviewed project. Add table rows or a general text field where necessary, there is no desire to write short. Please feel free to adapt the formatting as needed.

Projects Reviewer Information		
1	Name and Surname	
2	E-mail	
3	Organisation	

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Background information			
[Project Name] – [Demo Name (optional)]		Starting date	
		Ending date	
What is the objective of the project under review? *[provide a brief explanation of the main objectives of this project]*			
Has the project been completed?			

Consumer type		
Classification of target group consumers and clustering strategies		
Which types of consumers were foreseen (private persons, small businesses, local energy groups ..) and how were they defined? Which roles were assigned to the consumer (consumer, prosumer, proprietor, …)? *[Provide a short description and reference to the relevant documentation, add lines as necessary]*		
Consumer	Description, characteristics, role	References
Did the project discuss different user profiles? How did they differ from the consumer type? Were they steady or a consumer could have a different user profile at different times? *[Please provide a short description and reference to the relevant documentation, add lines as necessary]*		
User Profile	Description	References

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Were any clustering strategies applied and which? (A clustering strategy is the active grouping of consumers based on certain criteria such as spatial, load profile, socio-economic, RES, storage, etc.)		
Did the project consider collective action schemes, such as local energy communities, etc.? *[Provide a short description and reference to the relevant documentation, add lines as necessary]*		
Consumer/Group	Description, characteristics, role	References

Consumer Engagement		
Did the project develop or apply strategies for consumer involvement?		
If yes, please describe briefly the strategies, the frame conditions for application and related references.		
Consumer engagement strategy	Description, frame conditions	References
How did the use cases reflect the applied consumer engagement strategies? Please describe them briefly and reference to the relevant documentation.		
Consumer engagement strategy	Use case	References

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Did the project develop business models based on the applied consumer engagement strategies? Were incentives applied and which kind (monetary, environmental, social)? Please describe them briefly and reference to the relevant documentation.		
Consumer engagement strategy	Corresponding business model and incentives (monetary, environmental, social)	References
What services did the project define to market customer's flexibility?		
Flexibility description	Service defined	References
Did the project deal with billing, tariffs and energy plans?		
If yes, please indicate in the table with the corresponding references.		
Billing concepts	Energy plans and tariffs	References

Consumer Interaction	
Were interactions from consumer groups considered and supported? Which types of interaction and in which constellation (consumer to	

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consumer, consumer to group, consumer to platform, …)?			
If yes, how were the consumer interactions integrated and handled? Can you define them in terms of context, handling, technical implementation and interaction sequences? *[Provide a short description of the consumer interaction context and reference to the relevant documentation, add lines as necessary]*			
Consumer interaction	Description	Actors and Roles (DSO, TSO, MO)	References
…			
…			
Did the project consider organisational activities such as training and educational activities or support services?	*[Y/N]*		
If yes, how were these organized and incentivized? Can you define them in terms of background, target group, organisation, incentives, acceptance and performance evaluation? *[Provide a short description of the consumer interaction context and reference to the relevant documentation, add lines as necessary]*			
Organisational activity	Description: background and organisation	Target group, incentives, acceptance, evaluation	References
…			
…			
…			

Interfaces

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Interface, software that links operators (market, system, and others) on data exchange for FSP integration and consumer interactions

Were any specific interfaces between consumers and markets or grid operators developed within the project?	*[Y/N]*

If yes, for what are these interfaces? Can you define them in terms of information models, timing requirements and interaction sequences? *[Provide a short description of the interface and reference to the relevant documentation, add lines as necessary]*

Developed interfaces	Description	Actors and Roles (DSO, TSO, MO)	References
#1			
#2			
#3			

Tools

Were tools (like forecasting, data exchange, bid selection/optimization, pre-qualification, settlement, flexibility registers, state estimation, coordination, baseline calculation tools, etc.) developed in relation with the above-mentioned interfaces and specifically to enable consumer participation either directly or through an FSP?	*[Y/N]*

If yes, what are these tools? *[Please provide a short description of the tool functionality and related references, add lines as necessary]*

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Developed tool	Description	References
#1		
#2		
#3		

Hardware requirements		
Did the project discuss hardware requirements on consumer side?		
If yes, please described the hardware requirements on consumer side (type of hardware, minimal requirements, ownership, provided or leased or bought by the consumer, installation)		
Required hardware	Conditions	References

Communication and data exchange	
Hierarchy, standards, data models and data privacy	
Did the project define communication and data exchange requirements for the communication with consumer entities, and if yes, among which actors? Please describe briefly.	
Did the project consider different hierarchies and constellations in terms of communication with the consumer (centralized, decentralized, distributed, agent-based, data aggregator, local optimization)? Please describe in the table.	

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Hierarchy	Description and conditions	References
Which protocols and standards were applied? Please list in the table with the corresponding reference.		
Standard or protocol	Application description	References
Which data models were used? Please list in the table with the corresponding reference.		
Data models	Description and context	References
Which data privacy and data protection measures were taken? Please list in the table with the corresponding reference.		
Data privacy/protection	Description	References

Data Analytics		
Were any data analytics applied in terms of consumer management (AI, Big Data, IoT), and if yes, at which level (consumer, aggregator, …)?		
If yes, please explain in the table which methods were used and the corresponding application.		
Data analytics method	Application: description and level	References

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8 Appendix II UC analysis

Narrative

Project		
BUC		
Short Description		
Summary of Phases		

Roles

Actor	Actor description	Further information specific to this use case

Sequence diagram

Functions for GA, FP, DSO, TSO, MDO

Actor

Function	
Description	
Input/Output	
Subfunctions	

Interfaces

Interface
Involved Roles
Business Object

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Data Description
Data Volume (optional)
Frequency (optional)
Reliability (optional)
Data Model
Communication Protocol

9 Appendix III Questionnaire Interaction with the demos

Question	Answer	Notes, references, additional info
General		
Current stage of development and time plan		
Products and services		
Applied BUC and SUC and current state of the definition		
Previous work on requirements		

Observations or conditions, which could introduce additonal requirements	
Specific expectations on WP4 according to the time plan (deadlines)	
TSO	
What Data is exchanged at TSO level for interoperability towards the distribution system?	
What are the gaps in terms of data exchange between TSOs, DSOs and market?	
What interfaces are used between market and grid operations?	
What developments are needed/expected in terms of new interfaces/sequence diagrams between market and grid operations?	
DSO	
What Data is exchange between DSOs and the flexibility Market for CM and VC integration?	
What are the needed interfaces for this exchange to happen?	

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Technical requirements and the specifications at the level of the interfaces required for the markets and platforms for grid services (e.g. between DSOs and TSOs: DSOs and DSOs; DSO and suppliers/aggregators/consumers/prosumers)

Customer

Are consumers going to be involved and which type (residential, industrial, energy communities, aggregators, cross-domain)?

If yes: which products are going to be offered to consumers?

If not: what led to this decision and how could this issue be addressed/removed in future?

Are strategies for consumer engagement going to be integrated? Other measures to inform consumers?

If consumers are going to be involved: which incentive is planned? Has it been developed especially within OneNet or has it been in place and it is implemented exactly in the way it is for all customers?

In case of aggregators: are these commercial and who is operating them?

In case of residential consumers:

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Which devices are they required to have? Are there any minimal requirements for the involvement or other limitations?	
Which communication is foreseen for consumers? Customer to aggregator or customer to customer? Communication to the market/DSO/third party or directly to market?	
Which operation schemes are foreseen: direct participation at the market, centralized to an aggregator, decentralized?	
What data is exchanged with the customer and among which instances?	
Are there limitations for the participation of end customers? Which?	
Is there a concept for interoperability which includes the customer?	
Which interfaces are foreseen for customers and to which instances/platforms/market?	
Are further interfaces necessary?	
Interfaces: technical requirements and specifications	

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