[Technical foundations]

21 June 2024

OPENTUNITYproject.eu

Deliverable details

Title	WP	Version
Technical foundations	2	1.1

Contractual delivery date	Actual delivery date	Delivery type*	Dissemination**
M11 (November 2023)	M11 (November 2023)	R	PU

*Delivery type: R: Document, report; DEM: Demonstrator, pilot, prototype; DEC: Websites, patent fillings, videos, etc; OTHER; ETHICS: Ethics requirement; ORDP: Open Research Data Pilot.

Dissemination Level: **PU: Public; **CO**: Confidential, only for members of the consortium (including the Commission Services)

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Version	Date	Person	Action	Status***
0.1	19.10.2023	Álvaro Nofuentes	Table of Content	Draft
0.2	23.10.2023	Álvaro Nofuentes	First content added	Draft
0.3	08.11.2023	Álvaro Nofuentes	Sections 1 to 7 and ANNEXES finished	Draft
0.4	14.11.2023	Álvaro Nofuentes	Section 8 added and ready for Peer Review	Draft
0.5	21.11.2023	Vassilis Boglou; Dimitrios Lagos	Peer review	Final
1.0	28.11.2023	Álvaro Nofuentes	Version ready to submit	Submitted
1.1	21.06.2024	Federico Giani	Removal of confidential info	Submitted

***Status: Draft, Final, Approved, Submitted (to European Commission).

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Keywords

Foundations, OPENTUNITY objectives, innovations, methodology, Use Cases, requirements, Key Performance Indicators, Pilot Sites

Executive Summary

The OPENTUNITY project in its entirety is driven by three core strategic objectives, for the achievement of which, the innovative solutions and technologies to be developed within the project, contribute directly.

- SO1. Decarbonization of EU society:
- SO2. Citizen and stakeholder empowerment:
- SO3.Ensure quality of supply in a context of increase of RES:

In order to achieve the aforementioned goals, a specific methodology is followed regarding the definition of the requirements that should be met by the technologies to be developed and deployed, the definition of the Use Cases for testing the actual impact of the proposed solutions and the identification of Key Performance Indicators that enable the unbiased evaluation and quantification of the Project outcomes.

Requirements' definition

Through the requirement analysis it is possible to identify all necessary attributes, capabilities, characteristics, or qualities of a system that cover the needs of its users. To this end, each requirement describes measurable conditions the fulfillment of which is possible to be evaluated. The Volere methodology is being used, since it assists in the description, formalization and tracking of the project requirements in an explicit and unambiguous manner. Additionally, it is useful not only in the initial phases of OPENTUNITY, but also during the implementation phase and management in general.

For better organization of the work, **the 82 requirements are categorized into sixteen classification groups**. Each requirement is characterized by its priority (5: high; 4-3: medium; 2-1: low). High priority is assigned to requirements that either realize a key innovation of the project or are needed to realize it and are, thus, necessary for achieving the goals of OPENTUNITY.

Use Cases' definition

Even though the Use Case methodology defined in IEC 62559-2:2015 originally derives from the software engineering discipline, the straightforward manner it offers for describing the intended functionalities (static as well as dynamic) of the system under study renders it also appropriate for application in the smart grid. In fact, the Use Case Methodology is the basis upon which the Smart Grid Architecture Model (SGAM) framework is built.

These Use Cases are formulated using a specific template that supports the process of mapping each characteristic of the Use Case to the SGAM layers of the Architecture task.

The **21 Use Cases defined are categorized under five HL-UCs**. These HL-UC/scenarios are linked with the Pilot Sites

- HL-UC 1: Horizontal
- HL-UC 2: Greece
- HL-UC 3: Slovenia
- HL-UC 4: Spain
- HL-UC 5: Switzerland

One important part of the Use Cases is the identification of the actors involved in each one of them. In order to establish a common understanding and language regarding the actors involved in the Use Cases defined within OPENTUNITY, **a list of actors is also defined**. This list includes a definition commonly accepted by all partners.

Key Performance Indicators

In order to evaluate the results of the solutions proposed and implemented within OPENTUNITY it is necessary to quantify the tangible and measurable impacts which contribute to the specific OPENTUNITY objectives. To this end, the **49 OPENTUNITY KPIs** were defined according to the identified needs of the

Use Cases. Consequently, each Use Case could use more than one KPI, while one KPI could be appropriate for more than one Use Case.

Last but not least, it was necessary to know the characteristics of the Pilot Sites in order to better define the Use Cases. The four pilot sites in Greece, Slovenia, Spain and Switzerland serve as real test bed for the solutions developed within OPENTUNITY. More specifically, the pilot site formal analysis comprises an outline of the current situation in terms of infrastructure as well as services offered to the end-users and applications that facilitate the management of each pilot site. The different needs of the end-users in each pilot, renders each one appropriate for testing and demonstrating a variety of UCs as well as for deploying several of the OPENTUNITY tools. It is possible to have an overview of the Pilot Sites in Figure 1.

Figure 1. OPENTUNITY Pilot Sites summary

The analysis of the Pilot Sites have been made following these axes:

- Current Situation.
    - Assets related to Power Grid.
    - Assets related to Homes/Buildings.
- Equipment shortage list.
- Challenges and criticalities.

Copyright statement

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2 INTRODUCTION

2.1 Purpose of the document

Task 2.1 "Use cases, requirements and KPIs definition" (along with Task 2.5 "Pilot Sites Analysis") under WP2 lays the foundations for the technical aspects of the project. Since the ultimate goal is for the technological solutions proposed within OPENTUNITY to be tested and studied in real applications, a set of methodologies are necessary for the systematic analysis of both the conditions under which the technological solutions are expected to operate as well as of the new environment formed and the new opportunities created by the widespread application of the proposed products. More specifically, the content of this document reflects the output produced by the close cooperation of the participating partners in order to serve as input for Task 2.4 "Open and interoperable architecture" where the architecture will be designed and analyzed. Consequently, and in view of the multidisciplinary nature of the project, the current document reports systematically the high quality, knowledge-intensive output produced during the previous months.

2.2 Scope of the document

This document records the accumulated collective knowledge produced through the cooperation of the partners within Task 2.1 (each one contributing with its respective expertise) in order to define the requirements and use cases that serve as a basis for forming the project architecture and for defining the demonstration scenarios and activities in the pilot sites. Furthermore, a set of Key Performance Indicators (KPIs) for assessing the impact of the project products is also produced.

2.3 Structure of the document

The deliverable starts with the explanation of the objectives of the project and the OPENTUNITY innovations that will allow the consortium to reach them. With this required context, the reader will be able to go to the core part of the deliverable in which the Use Cases, the requirements and the KPIs are analysed. A deep analysis of the different OPENTUNITY Pilot Sites can be found afterwards. At the end of the deliverable, in the annexes, it is possible to find the detailed definition of the Use Cases, the requirements and the KPIs.

3 OPENTUNITY OBJECTIVES

OPENTUNITY project aim can be mapped into 3 Specific Objectives (SO):

- **SO1. Decarbonization of EU society:**
  This specific objective has as starting point the decarbonization of demo sites investigating replicable solutions. The increase of distributed RES and the increase in energy efficiency resulted by the project will directly address this point. The integration of different verticals like electromobility and the efficient management of CHP (Combined Heat and Power) and district heating will also favour this SO. It is also noteworthy that these technologies will not be only beneficial for decarbonizing, but also for improving the air quality of demo sites.
- **SO2. Citizen and stakeholder empowerment:**
  Another important layer of the OPENTUNITY project is the socioeconomic point of view. It is essential for OPENTUNITY to ensure that, apart from decarbonizing the society, the results have a direct impact on the economic welfare of EU citizens. This implies, of course, reducing their energy expenditures but also empower them and give them a role in the energy sector of the future. Finally, it is also important to increase the energy dependency of EU countries in order to empower both citizens and institutions.
- **SO3.Ensure quality of supply in a context of increase of RES:**
  OPENTUNITY will not smarten the grid just to provide greener and cheaper electricity, but also to provide a better quality of supply. Energy is the basis of the human activities and it is necessary that projects like OPENTUNITY ensure that the energy distributed and supplied to EU households and industries is properly managed. The continuous increase in Distributed Energy Resources implies new challenges to grid Operators and OPENTUNITY will facilitate its short and long-term operation in this new paradigm.

4 OPENTUNITY INNOVATIONS

In order to facilitate the establishment of the OPENTUNITY ecosystem, a series of innovations will be developed. To facilitate the understanding of these **OPENTUNITY project innovations** (which obviously address the objectives previously described), they will be packaged in the following 2 clusters:

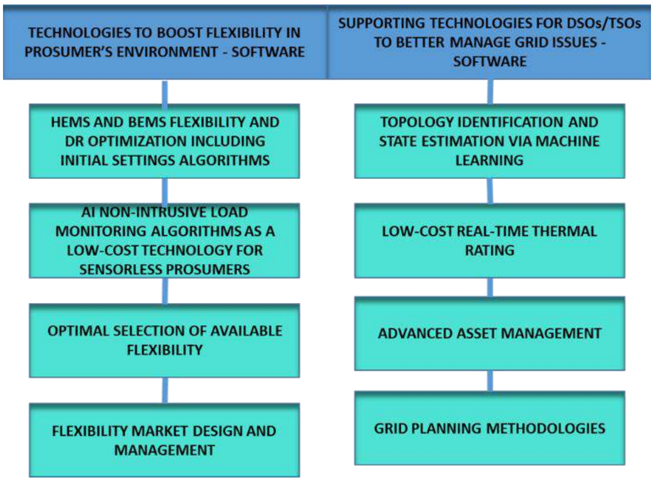


Figure 2. OPENTUNITY Technical innovations

The software innovations will be modular so they can be included in already developed products like HEMS/BEMS from HYP, AMIBIT or ETRA (that will be used in OPENTUNITY demonstrations) **or DSO/TSO energy management platforms** from ETRA or HIVE (hat will be used in OPENTUNITY demonstrations).[1] These innovations will guarantee the technical performance within the project, and the replicability and market transferability after the project completion.

4.1.1 TECHNOLOGIES FOR PROSUMERS

4.1.1.1 HEMS AND BEMS FLEXIBILITY AND DR OPTIMIZATION INCLUDING INITIAL SETTINGS ALGORITHMS

OPENTUNITY HEMS and BEMS will support the most common standards in order to communicate with smart meters and IoT devices. It is also noteworthy that BEMS/HEMS will be made modular in order to provide specific functionalities to actors which may have necessities different from pure electricity management of a building and to facilitate interoperability. This refers to provide modules to specific flexibility management of EVs (and charging points), storage, CHP and other assets utilized in OPENTUNITY demo sites. Moreover, OPENTUNITY will also develop an initial settings algorithm for prosumers in order to automatically generate a DR profile to be followed in case of DR campaigns. Thus, the **project alleviates**

[1] In terms of replication, OPENTUNITY innovations will be able **to be integrated within external vendors' products since they will be interoperable.**

prosumers' mind on how to react to DR signals, being sure that they won't affect its comfort and behaviour.

The stakeholders that will benefit from this innovation will be ESCOs, aggregators, small and medium prosumers, facility managers and EV carsharing companies.

4.1.1.2 AI NON-INTRUSIVE LOAD MONITORING ALGORITHMS AS A LOW-COST TECHNOLOGY FOR SENSORLESS PROSUMERS

Non-intrusive load monitoring (NILM) is a technology that estimates energy consumption of individual appliances, which can be implemented in real-time and can provide controllable feedback in terms of energy behavior and personalized recommendations to consumers [1]. **NILM techniques do not require the installation of sensors in each device which implies a reduction of energy efficiency expenditures.** OPENTUNITY will develop advanced NILM algorithms based on Artificial Intelligence models that may also be embedded into low-cost IoT smart energy meters, which will constitute the basis for a more performant energy monitoring and DR implementation in the project.

The stakeholders that will benefit from this innovation will be ESCOs and small and medium prosumers.

4.1.1.3 OPTIMAL SELECTION OF AVAILABLE FLEXIBILITY

OPENTUNITY will present a logical framework for assessing the technical specification of smaller, decentralized demand response units. A dedicated tool will be developed and deployed, which will utilize predicative analyses and big data, and through the use of AI carry out optimal selection of demand response units according to their predicted availability. A wide range of input parameters will be considered – for e-vehicles, average daily distance driven, charge patterns, estimated state of current charge, etc. Furthermore, for households a dedicated home energy management systems platform will be deployed that will ensure optimal distribution of activations from a range of households.

The stakeholders that will benefit from this innovation will be Aggregators and their clients (energy communities, EV carsharing companies…).

4.1.1.4 FLEXIBILITY MARKET DESIGN AND MANAGEMENT

A clear framework for local flexibility market adaption will be established for each of the pilot sites. OPENTUNITY will pursue to serve the different requirements and operational processes according to specific grid problems in each pilot. **A wide range of products will be considered based on customer needs.** In addition, **the technology agnostic OPENTUNITY Platform will enable participation of large loads as well as distributed small-scale flexibility down to 1 kWh** bundled in portfolios with higher volumes. Building on this concept, OPENTUNITY is enabled to trial various technologies and decentralized demand response units to integrate with the market to monetize their flexibility and reveal their full socio-economic benefits.

The stakeholders that will benefit from this innovation will be Flexibility Market Operators but also TSOs, DSOs and market actors participating in flexibility markets.

4.1.2 TECHNOLOGIES FOR GRID OPERATORS

4.1.2.1 TOPOLOGY IDENTIFICATION AND STATE ESTIMATION VIA MACHINE LEARNING

OPENTUNITY will develop a Machine Learning-based software module for distribution networks that will jointly estimate the systems' states and grid configuration topology. When installed, this module will not require sensors and measurement devices to analyze and identify the topology of the DSO grid. OPENTUNITY technology will track the voltage and current profile's behavior in each feeder with a Deep Learning algorithm and the project will be able to detect switching devices' status and identify the different distribution system's topologies and the loads connected.

The stakeholders that will benefit from this innovation will be DSOs (especially small ones).

4.1.2.2 LOW-COST REAL-TIME THERMAL RATING

The Line Rating is an important characteristic that influences the electricity market operation. Static Line Rating methodologies usually provide conservative estimations of the actual capacity of the line. Advanced methods, called Real-Time Thermal Rating provide more accurate estimation using weather forecast across the line and measurements from sensors installed in the line. **The necessity of multiple sensors increases the cost of such solutions** [2]. However, **OPENTUNITY proposes a new methodology to achieve low-cost real-time thermal rating without installing extra sensors.** The starting point of this methodology will be accurate numerical weather prediction. An advanced algorithm will be developed using machine learning technics and big data analytics.

The stakeholders that will benefit from this innovation will be DSOs (operating MV lines) and TSOs.

4.1.2.3 ADVANCED ASSET MANAGEMENT

The ambition of OPENTUNITY is to utilize the data coming from various sensors (including electronic meters and smart appliances) and develop new risk assessment methodologies and methodologies for the optimization of maintenance planning. Modern distribution grids have huge volume of measurements from various sensors and measuring devices; and the extraction of knowledge requires advanced techniques. The use of advanced analytics and machine learning algorithms (e.g support vector machines) will allow the **development of accurate aging models** (that may lead to second step developments of algorithms for optimal maintenance) and the **estimation of non-technical losses**.

The stakeholders that will benefit from this innovation will be DSOs and TSOs.

4.1.2.4 GRID PLANNING OPTIMIZATION

The OPENTUNITY approach in system planning will be align the goals of Green Deal and Fit for 55 focusing on the cross-sector integration. In order to create a vibrant cross-sector ecosystem, the starting point is the identification of interconnections and the analysis of dependencies with other energy verticals (such as electromobility and CHP). Next the adaptation in the existing planning methodologies will be identified, focusing on the new risk index and variable that should be introduced. Finally, **advanced optimization techniques will be used to provide solution for the new formulation of the planning** problem.

The stakeholders that will benefit from this innovation will be DSOs and TSOs.

4.1.3 METHODOLOGIES FOR ENHANCING INTEROPERABILITY

Apart from the innovations mentioned previously, OPENTUNITY is also generating methodologies for **enhancing interoperability in both prosumer and grid side**. These methodologies will not imply major IT developments efforts (although some IT development will occur) so **they do not have associated Use Cases.**

4.1.3.1 PLUG AND PLAY RECOGNITION FOR FLEXIBILITY DEVICES

Information about the nominal characteristics of the appliances as well as other information that is useful for flexibility extraction (e.g. operational limits) will be analysed by OPENTUNITY and included in a QR code. A simple code can provide this rich information about the characteristics of underlying appliances and/or energy assets. **This mechanism can significantly reduce configuration/commissioning effort and errors in a true do-it-yourself manner by the average citizen** (and even potential non-skilled ones like some elderly people), scanning a QR code using a mobile app can enable the integration of an appliance into a HEMS/BEMS system.

The stakeholders that will benefit from this innovation will be OEMs, ESCOs and small and medium prosumers.

4.1.3.2 FACILITATING INTEGRATION OF DSO AND TSO ICT INFRASTRUCTURES INTO ENERGY MANAGEMENT SYSTEMS

OPENTUNITY will create an automated methodology that will be able to be used in different pilots making simple for DSO/TSO employees to integrate the required data (mainly GIS and topology) into their Grid Energy Management Platform. The methodology will be complemented by a simple user interface based on previous ETRA developments. This interface will allow the user to work with the topology integration methodology in a user-friendly manner, to modify the appearance of the elements and match them to the related GIS coordinates.

The stakeholders that will benefit from this innovation will be ICT companies (developing energy management systems) and DSOs.

5 USE CASES

5.1 USE CASES AS BACKBONE OF THE PROJECT

The Use Case (UC) Methodology to be employed in OPENTUNITY has been originally defined in IEC 62559-2:2015 [3] **to cover the needs of the software engineering.** However, its advantages render it also appropriate for application in the smart grid. More specifically [4]:

- It offers a systematical manner for gathering all necessary information regarding functionalities, processes and respective actors.
- It facilitates the coordination among various stakeholders as it ensures the common understanding of complex processes.
- It forms the basis for further development of the functionalities of the system under study.

The Use Case Methodology includes a template where all necessary information for a specific process is described: from high-level information, such as the name of the UC, to a detailed step-by-step analysis of the realization of the UC as well as the actors involved.

This Use Cases methodology is the basis for the architecture definition through the Smart Grids Architecture Model (SGAM) framework [5]. It can be described as the architectural structure of a practical methodology where each particular Use Case (UC) can be modeled and analyzed from different aspects. The most important factor while modeling a UC is the coherency of the whole process, as well as the production of an analytic and easy to understand model. In Deliverable 2.3 "Open architecture report". This SGAM Methodology will be detailed.

The Use Cases described at the first part of the project (and reported in this deliverable) **will be the guide for the demonstration activities.** These demonstration activities, to be performed during the last year of the Project, will allow the OPENTUNITY Developers and the End-Users to test the OPENTUNITY innovations in real-life conditions and thus to check their suitability to reach OPENTUNITY objectives.

5.2 OPENTUNITY HIGH-LEVEL USE CASES

At the beginning of the project, the consortium defined five different High Level Use Cases (HL-UC), that **can be understood as scenarios**, in order to structure the necessities of the project and define the most appropriate Use Cases within each one of them. **These HL-UC/scenarios are linked with the Pilot Sites.** Hereafter it is possible to find a description of each HL-UC.

5.2.1 HORIZONTAL

They are the **Use Cases that will be tested in more than one Pilot Site.** In the Horizontal Use Cases are included both Grid and Prosumer's innovations. Every pilot site is testing Horizontal Use Cases, ensuring a cross-validation of the technologies. There are 10 Horizontal Use Cases.

5.2.2 GREECE

There is **one Use Case that will be just tested in Greece**. They are interested in new planning methodologies for considering future increase of RES.

5.2.3 SLOVENIA

There are **three Use Cases to be tested in Slovenia**. The main aim of these Use Cases is to take advantage of the flexibility that AVANTCAR's fleet can provide.

5.2.4 SPAIN

There are **five Use Cases to be tested in Spain**. Their main interest is to increase the intelligence of their grid in order to facilitate the establishment of energy communities.

5.2.5 SWITZERLAND

There are **two Use Cases to be tested in Switzerland**. The main aim of these Use Cases is to take advantage of the energy assets of the energy community that will be established in order to avoid grid issues.

5.3 USE CASES MAPPING

In order to have a clear insight of the different Use Cases defined in OPENTUNITY, a Use Cases map has been created. The complete description of the different Use Cases is in ANNEX II: LIST OF USE CASES.

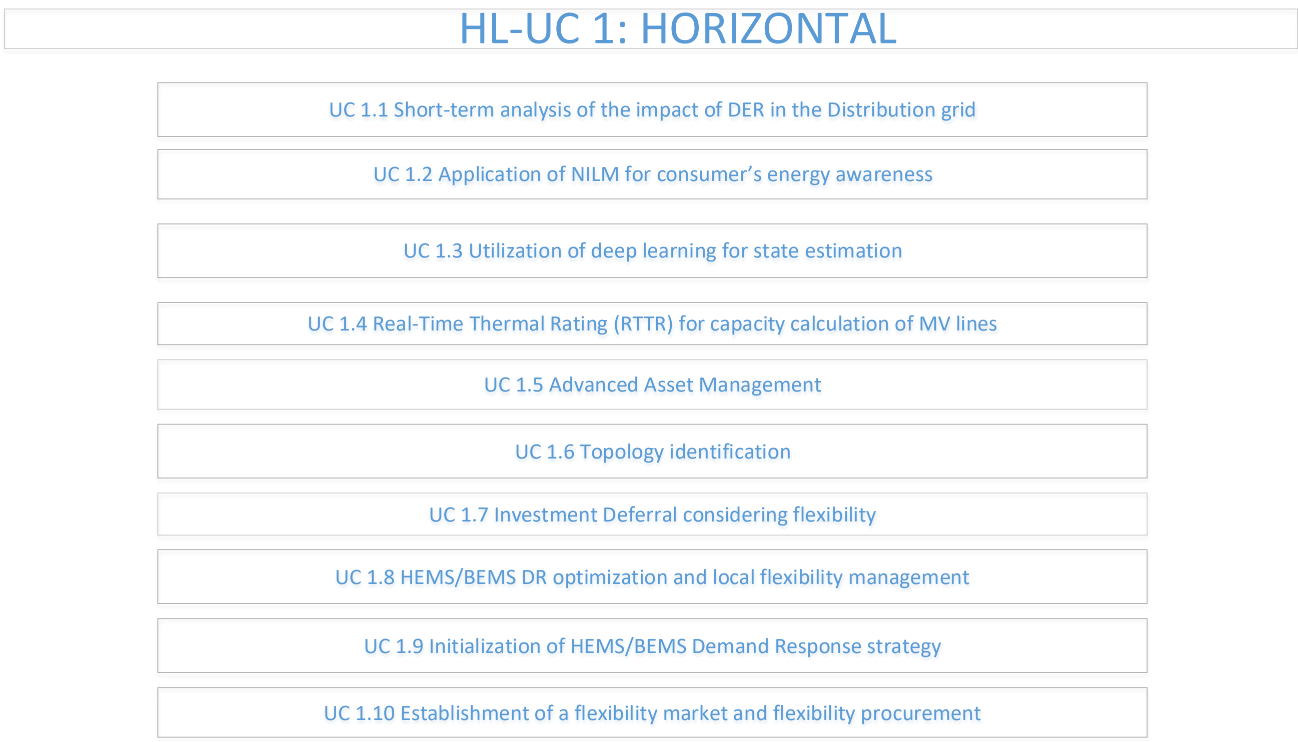


Figure 3. Use Cases Mapping (1)

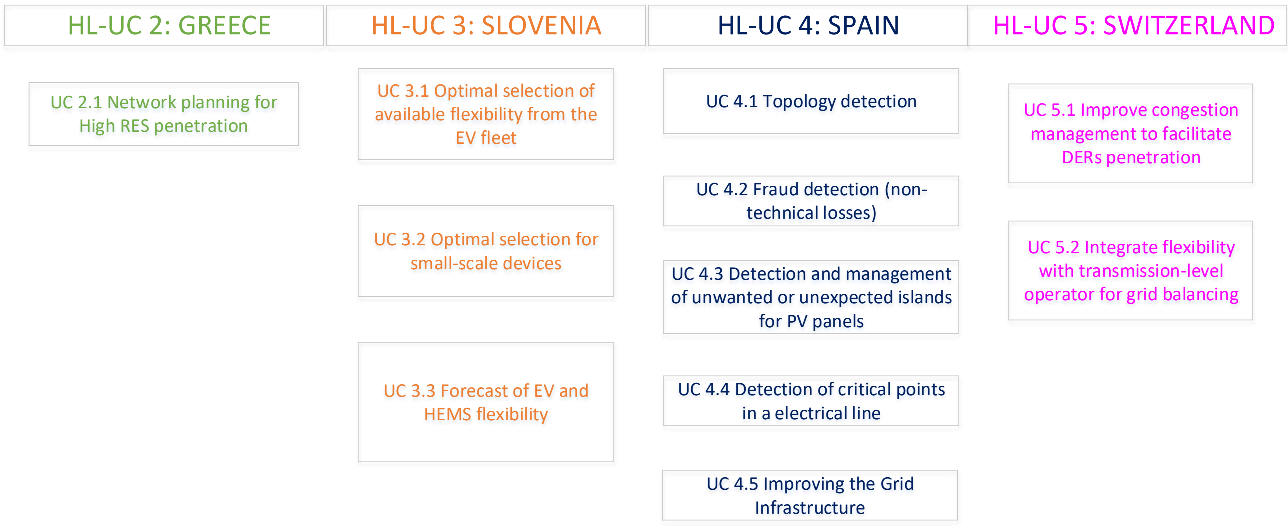


Figure 4. Use Cases Mapping (2)

Finally, the next paragraph serves as a summary of the number of Use Cases that will be tested in each Pilot Site in total (Horizontal + Specific):

- **Greece:** 7 Use Cases (6 Horizontal + 1 Specific).
- **Slovenia:** 10 Use Cases (7 Horizontal + 3 Specific).
- **Spain:** 12 Use Cases (7 Horizontal + 5 Specific).
- **Switzerland:** 9 Use Cases (7 Horizontal + 2 Specific).

6 REQUIREMENTS

As a result of Task 2.1, **82 requirements have been identified** in total, each one intended to describe specific characteristics of the OPENTUNITY innovations. While in this section it is possible to find the definition of the methodology and the importance of these **82 requirements,** the complete list can be found in ANNEX III: LIST OF REQUIREMENTS.

For better organization of the work, sixteen classification groups of requirements were identified:

Advanced asset management (AAM)
AI non-intrusive load monitoring algorithms as a low-cost technology (AI)
Architecture (ARC)
Decentralized Identifiers (DI)
Flexibility market design and management (FMD)
General (GNR)
Grid Planning Methodologies (GPM)
HEMS and BEMS Flexibility and DR optimization (HBF)
Integration of DSO and TSO ICT infrastructures into energy management systems (IIE)
Interoperability with other platforms and management of their historical data (IPM)
Low-cost real-time thermal rating (LCR)
Optimal selection of available flexibility (OSF)
Other (OTH)
Plug and play recognition for flexibility devices (PPR)
Topology identification and state estimation via machine learning (TML)
Upgrading of SGAM methodology for involving blockchain-based technologies (BCT)

Figure 5. Requirements classification groups (Volere screenshot)

6.1 REQUIREMENTS METHODOLOGY

The Volere methodology is not new to some of the project partners. It was initially used by a number of the project partners in the NOBEL GRID [6] , WiseGRID [7] and CROSSBOW [8] projects (among others) where it was used mainly because of its simplicity. It helped project partners to describe, formalize and track the project requirements in an explicit and unambiguous manner. Besides, being successfully realised in the above-mentioned previous projects, the Volere methodology was selected for the following three reasons:

1. It requires simple steps to identify and formalize the requirements in an unambiguous manner.
2. It provides an easy process to track and evaluate the progress of the project.
3. Several project partners are already experienced in using the Volere methodology.

Consequently, the application of the Volere methodology is not only useful in the initial phases of the project for specifying requirements, but it is also helpful in specifying a reference point for the later stages. During the use case analysis, for example, it can be used to ensure that different use cases cover different aspects of the requirements and that all important requirements are covered by them. During the implementation and management, it can be used to track and evaluate the progress of the individual work packages and the overall project. Besides being efficient and easy to use, the Volere methodology provides a mechanism for all partners to specify the requirements in a standard format. Thereby, specifying additional context of a requirement such as the rationale and the acceptance criteria for every requirement helps to build a common understanding of the overall system. Furthermore, defining priorities helps to clarify the focus of the project.

6.1.1 REQUIREMENTS PRIORITIZATION

In order to prioritize requirements, the project consortium has introduced five different classes of priorities. These classes range from one (lowest priority) to five (highest priority) and the consortium has defined them as follows:

- **5 - High**: Requirements in this class are either realizing a key innovation of the project or they are needed to realize it. These requirements are necessary to achieve the goals of the project.
- **4-3 Medium**: Requirements in this class are not necessary to realize a key innovation but they are necessary or very helpful to realize the application prototypes. These requirements are important to the application developer.
- **2-1 Low**: Requirements in this class are necessary neither for realizing a key innovation nor for the application of the prototypes. However, in a broader context possibly beyond the scope of the project, they may be important.

As a consequence, for the success of the project, it is essential to fulfil the requirements with high priority. With respect to providing thorough support for product developers, it is important to realize the requirements with medium priority as well. The requirements with low priority, however, are not of immediate relevance to the project. However, their realization may provide additional features or benefits for applications or users that should be considered after all the requirements of the other two classes have been implemented successfully. In order to offer all the stakeholders and interested parties an insight into the prioritization process, the consortium has not only assigned categories to each requirement but also decided to include the main rationale for this classification in this document. Apart from being informative, this can also be helpful in later stages of the project where unforeseeable issues may require the introduction of new requirements, or changes to existing requirements.

6.1.2 VOLERE TOOL

Aiming to define an optimum and complete list of requirements, a web tool based on the Volere methodology was originally developed by ETRA and has been successfully used in different projects ever since. This web tool has facilitated the definition, the validation and the prioritization of the OPENTUNITY requirements. For security reasons, the access to the web tool has been restricted to authorized users.

Access to the web tool is granted after a successful identification on the system. The application allows the administrator to control the status of the validation process, from the initial definition to the final list of requirements, passing through the required validation and revision status.

6.1.2.1 SPECIFICATION PROCESS

The overall process of Volere as supported by the web tool is depicted in Figure 6. After an initial specification of requirements, the users can specify conflicts, dependencies and objections. After specifying them, they can iteratively revise the specification and identify additional issues until it is free of conflicts, dependencies and objections. The result will constitute the final list of requirements. The following subsections briefly outline the individual steps.

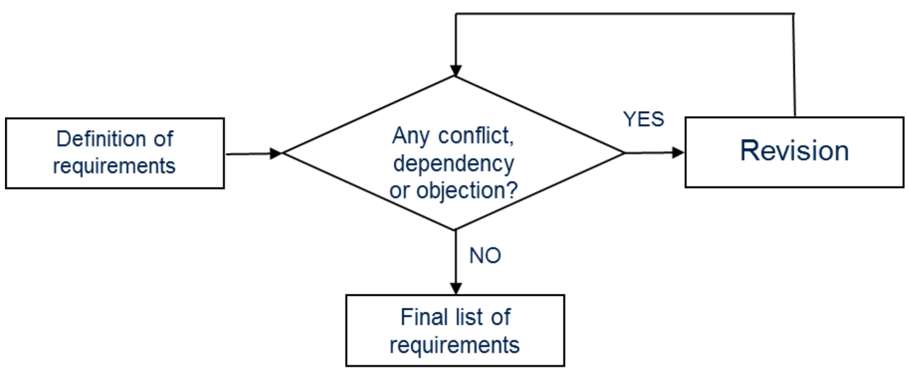


Figure 6. Requirement Specification and Validation Process

6.1.2.2 REQUIREMENT DEFINITION

In this first stage all the requirements needed to accomplish the project objectives must be defined. These will be refined in future stages. The most useful information and the main functionalities at this stage which are available at the home page, are (Figure 7):

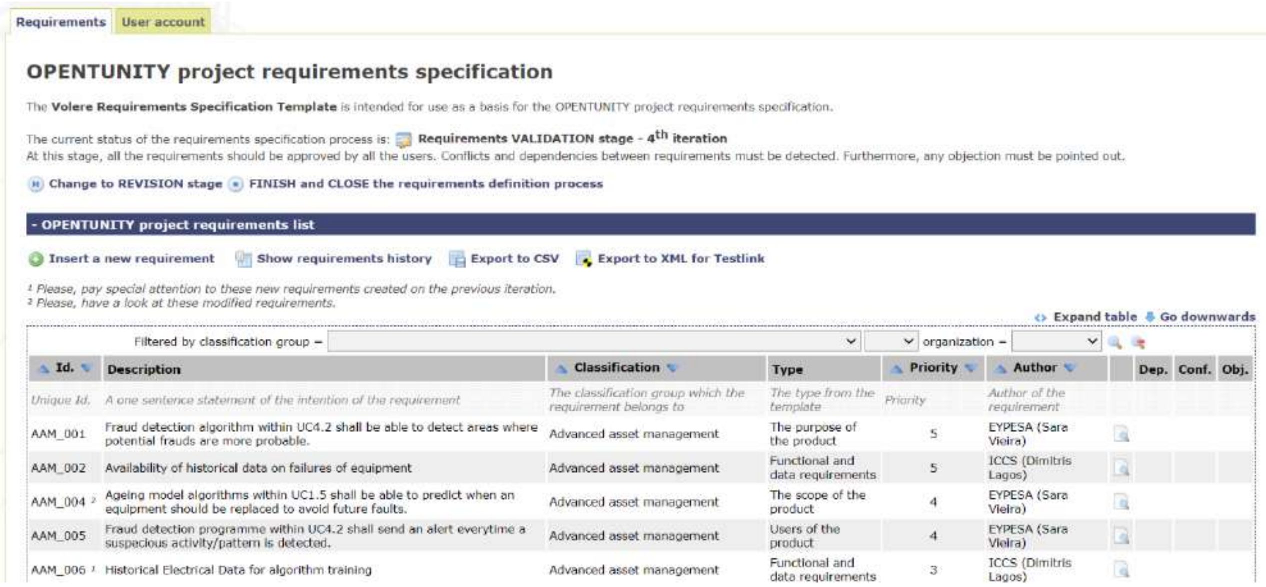


Figure 7. Volere home page

- List of requirements: The list of requirements with some additional options.
    - Filtering options: The list of requirements filtered per id., type and/or filtered per author.
    - Expand table: Show/hide some columns, displaying more or less information about the requirement.
- Requirements management: Modification options for requirements.
    - View a requirement.
    - Edit a requirement (only available for the author).
    - Delete a requirement (only available for the author).
- Requirements tracing: After the first validation, a new service is made available for keeping track of all the requirements history.
- Insert a new requirement: Opens a new window (Figure 8) to allow adding a new requirement. All the fields are required except for the "Comments" field which is optional. The required fields are:
    - ID: The scope of this requirement. Appended by an automatically generated sequential number, this ID uniquely identifies each requirement. This ID will be generated after the requirement has been added (Figure 9).
    - Description: A one sentence statement which describes the intention of the requirement.
    - Type: The type of the requirement as defined by Volere.
    - Rationale: A justification of the requirement.
    - Acceptance criteria: A measurement of the requirement for further verification that the solution matches the original requirement.
    - Priority: The importance for the customer of successfully implementing the requirement.

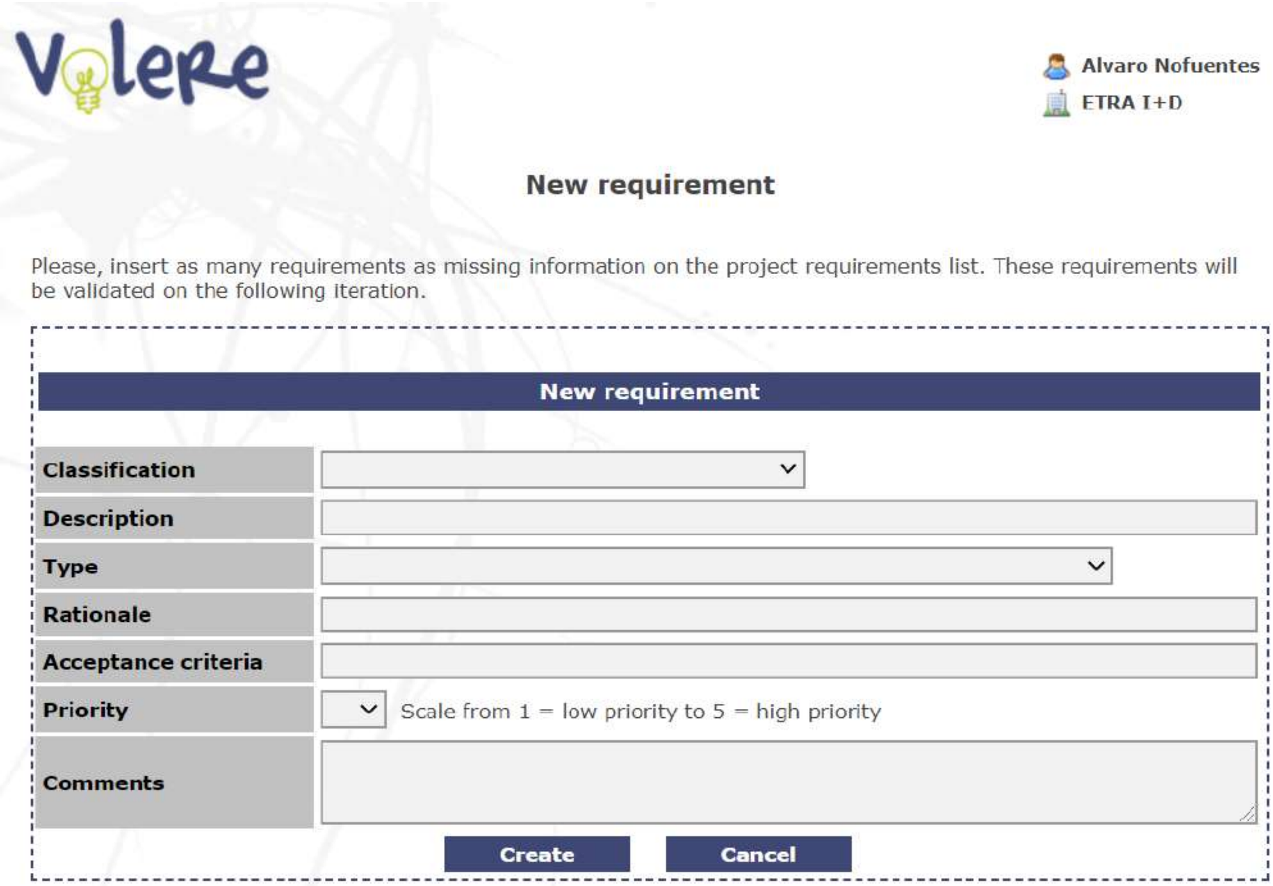


Figure 8. Definition of new requirements

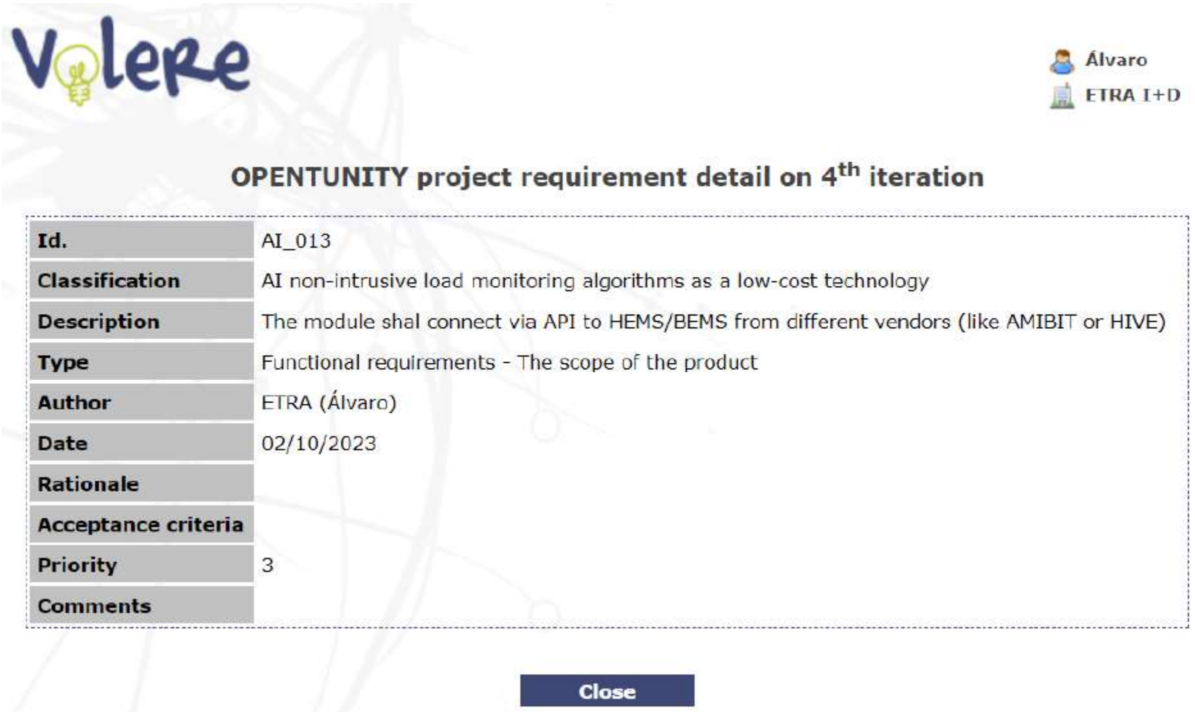


Figure 9. Requirement details

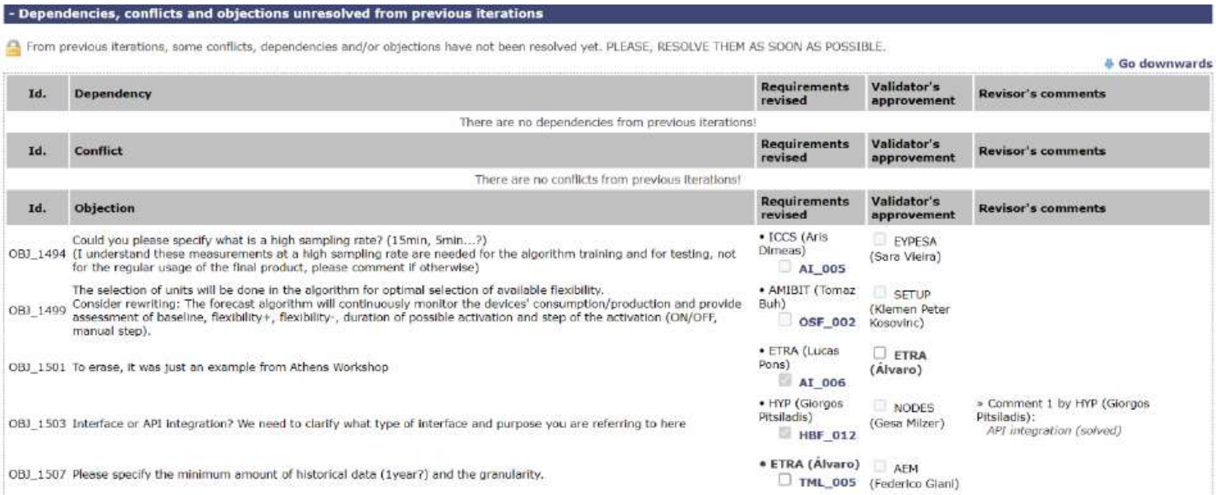
6.1.2.3 VALIDATION

After the initial definition of requirements, the validation process begins. All the requirements should be approved by all the users. At this stage, conflicts and dependencies between requirements must be detected. Furthermore, any objection must be pointed out:

- **Dependency:** Requirements that have some dependency on other requirements.
- **Conflict:** Requirements that cannot be implemented if another requirement is implemented or there is a conflict due to an insufficient definition of the requirement.
- **Objection:** A reason or argument due to disagreement, opposition, refusal or disapproval of the requirement.

6.1.2.4 REVISION

All the dependencies, conflicts and objections highlighted by the experts during the validation stage must be revised and solved by the author's requirements. However, if the authors do not agree with the validator's comments, they can include their own viewpoint in the "Revisor's comments" section for explanations and requirement clarifications. Note that only the authors of the requirements that must be revised are able to add comments to the dependency, conflict or objection sections.



- Dependencies, conflicts and objections unresolved from previous iterations

From previous iterations, some conflicts, dependencies and/or objections have not been resolved yet. PLEASE, RESOLVE THEM AS SOON AS POSSIBLE.

Go downwards

Id.	Dependency	Requirements revised	Validator's approvement	Revisor's comments
	There are no dependencies from previous iterations!			

Id.	Conflict	Requirements revised	Validator's approvement	Revisor's comments
	There are no conflicts from previous iterations!			

Id.	Objection	Requirements revised	Validator's approvement	Revisor's comments
OBJ_1494	Could you please specify what is a high sampling rate? (15min, 5min...?) (I understand these measurements at a high sampling rate are needed for the algorithm training and for testing, not for the regular usage of the final product, please comment if otherwise)	• ICCS (Aris Dimeas) AI_005	EYPESA (Sara Vieira)	
OBJ_1499	The selection of units will be done in the algorithm for optimal selection of available flexibility. Consider rewriting: The forecast algorithm will continuously monitor the devices' consumption/production and provide assessment of baseline, flexibility+, flexibility-, duration of possible activation and step of the activation (ON/OFF, manual step).	• AMIBIT (Tomaz Buh) OSF_002	SETUP (Klemen Peter Kosovinc)	
OBJ_1501	To erase, it was just an example from Athens Workshop	• ETRA (Lucas Pons) AI_006	ETRA (Álvaro)	
OBJ_1503	Interface or API integration? We need to clarify what type of interface and purpose you are referring to here	• HYP (Giorgos Pitsiladis) HBF_012	NODES (Gesa Milzer)	» Comment 1 by HYP (Giorgos Pitsiladis): *API integration (solved)*
OBJ_1507	Please specify the minimum amount of historical data (1year?) and the granularity.	• ETRA (Álvaro) TML_005	AEM (Federico Giani)	

Figure 10. Revision process

The checkboxes in the "Requirements revised" and "Validator's approval" columns in Figure 10, help the users to check the status of the revision and, alongside the possibility of adding clarifying comments, facilitate the interaction and communication between the author and the validator. For security reasons, the checkboxes in the "Requirements revised" column are only enabled for the authors of the requirements who can also add new comments. Moreover, for the same reason, the checkboxes in the "Validator's approval" column are only enabled for the validator.

The revision process consists of four steps:

- First, the authors should identify which requirements have been objected to or are involved in any conflict or dependency.
- Second, and after analysing the validator's viewpoint:
    - The author may agree with the validator and proceed to modify or delete the requirement or,

  - The author may disagree with the validator; therefore he/she should make appropriate comments trying to clarify the requirement with a better explanation or justify the intention of the requirement.

- Third, the author should mark the checkbox of the requirement as revised.
- Finally, the validator should be aware of the revised requirements and approve the actions taken by the author for resolving the dependency/conflict/objection.

The Volere tool allows every user to review the history of a requirement.

Id.		1st it.	1st rev.	2nd it.	2nd rev.	3th it.	3th rev.	4th it.	4th rev.
Id.	GNR_005			Added		Objection 1496 made by EYPESA (Sara Vieira): Why are these General requirements? They don't seem to apply to all the different modules. Would suggest to change it to HBF or OSF. Or do you think they apply to other modules as well? » Comment 1 by HYP (Giorgos Pitsiladis): Solved > updated as new requirements with the new IDs HBF_025-HBF_027. •GNR_002 •GNR_003	✗		
Description	End-users be able to declare desired flexibility assets and their (un)-availability at specific periods								
Type	Usability and humanity requirements								
Author	HYP								
Rationale									
Acceptance criteria									
Priority	3								
Comments									

Figure 11. Requirements revision history

7 KEY PERFORMANCE INDICATORS

The purpose of defining KPIs is to support the competent authorities (policy makers, regulators and network and market operators) in the decision-making process regarding the large-scale deployment of the innovative solutions demonstrated within OPENTUNITY. The design of KPIs in OPENTUNITY follows the same approach as the one applied in other projects like NOBEL GRID [6] , WiseGRID [7] CROSSBOW [8] or TRINITY [9]. Thus, the KPIs should be:

- Meaningful: they should relate with one or several expected project impacts, since they shall contribute in reaching the project's goals.
- Understandable: the KPI definition shall relate clearly with the expected impacts.
- Quantifiable: experimental values coming from field testing at an appropriate scale are used to develop ad-hoc simulation tools able to estimate the expected innovation impacts.

OPENTUNITY KPIs aim to present the added value of R&I results compared to the existing practices. The expected benefits (operational, technical and/or economical) that could be provided by OPENTUNITY versus the benefits already achieved by traditional solutions are quantified. Also, in order to understand OPENTUNITY KPIs, it is necessary to understand that OPENTUNITY technologies allow new activities and businesses that were not possible before the project, so some KPIs will deal with assessing the performance of these new opportunities (without comparing it with a previous situation).

The list of OPENTUNITY KPIs is shown hereafter (in ANNEX IV: LIST OF KPIs it is possible to find the whole information about each KPI).

Table 1. TRINITY KPIs

KPI ID	Description
KPI_01_Variability of the voltage	The variation of the supply voltage is defined as an increase or a decrease in the amplitude of the voltage, with respect to its nominal value.
KPI_02_NILM F1	The F1 score is a metric commonly used in the field of machine learning and classification tasks, including Non-Intrusive Load Monitoring (NILM). In the context of NILM, the F1 score assesses the model's ability to correctly identify when a specific device is turned on or off within a household.
KPI_03_Topology Identification MAPE	In the context of State Estimation, Mean Absolute Percentage Error (MAPE) is a metric used to evaluate the accuracy of the system state estimation. It quantifies the average absolute difference between the estimated state variables (such as voltage magnitude and phase) and the true values obtained from reliable measurements.
KPI_04_Capacity_Increase_By_DLR	This indicator will measure the average increase in the capacity of overhead lines, in terms of power, due to the deployment of dynamic line rating instead of static thermal rating.
KPI_05_Maximum Line Temperature Underestimation	This indicator will measure the robustness of the line temperature calculation that is used for the assessment of the dynamic capacity rating, using actual temperature measurements on the lines under test. The scope is to check whether the temperature of the conductor is underestimated.

KPI_06_ Accuracy on Asset Condition	This indicator will measure the accuracy of the classification of the pilots' assets to different condition states, using historical data on equipment provided by the DSO.
KPI_07_Topology Identification F1	The F1 score is a metric commonly used in the field of machine learning and classification tasks, including Topology Identification. In this context, the F1 score assesses the accuracy of identifying correctly both connections and impedances of the line infrastructure.
KPI_08_Increase in RES penetration	This indicator will measure the increase in RES production in % in a planning scenario where the flexibility sources are optimized as well as the network investments, compared to a Business-As-Usual scenario,
KPI_09_ Investment Deferral	This indicator will estimate how the installation and use of local flexibility can affect the deferral of investments in the distribution network considering Business-As-Usual methodologies for network upgrades implemented in the pilot sites, based on long term load and RES production forecasts.
KPI_10_Demand Forecasting Accuracy	The mean absolute error (over a given time period) between the actual and the forecasted demand (baseline).
KPI_11_Flexibility Delivery Precision	This KPI measures the extent to which the flexibility has been delivered according to the initial bid that had been made by the prosumer
KPI_12_Flexibility Potential	The amount of energy (for a given time period) that can be provided (given a specific baseline profile for a prosumer) by reducing or temporally deferring demand.
KPI_13_GHG Reduction	Reduction in GHG emissions which stems from DR
KPI_14_Load Reduction/Increase	The amount of energy decrease/increase (due to DR) compared to the actual demand of a prosumer for a given time period. In case of demand reduction, this expresses the energy savings.
KPI_15_Rate of Successful DR Events	The rate of successful DR events compared to the number of total DR requests.
KPI_16_Thermal Comfort Preservation	This KPI measures the extent to which temperature is beyond its associated limits (i.e., provides information by how much and for how long the temperature has been outside the predefined boundaries).
KPI_17_Local Average Voltage Deviation Index	The proposed metric is designed to evaluate the effectiveness of the participation of the energy system's operators to a local energy flexibility market. This will be achieved, by introducing an indicator for the voltages on the system's buses.
KPI_18_Cost Reduction due to Deferral of Grid Upgrade	The proposed KPI will calculate the cost reduction due to the deferral in the TSOs investments to replace or upgrade the network, by using Business as Usual (BaU) procedures, such as building new transmission lines. This KPI can help to assess the potential benefits of utilizing local flexibility markets to save

	money and reduce the environmental impact from the construction of new transmission lines.
KPI_19_Distribution Network Line Congestion	The Distribution Network Line Congestion (DNLC) indicator expresses the real power flow on the congested line as a percentage of the line power flow limit. Its purpose is to assess the overload of the lines and the strain that is caused.
KPI_20_Local Flexibility Market Requirements Coverage	The proposed metric is designed to evaluate the effectiveness of the Flexibility Service Providers (FSP) in meeting the requirements and demands of the DSO's local requirements. The KPI serves as a parameter for assessing the system's ability to provide flexibility services effectively to support the energy distribution network.
KPI_21_Potential offered flexibility	The proposed indicator is designed to measure the potential amount of flexibility that all flexible resources can offer through the market operator's platform.
KPI_22_Type of Flexibility Providers	This KPI is measured as the relation (in %) between the number of different technologies leveraged in the Demo and the number of types of technologies initially targeted by the Demo.
KPI_23 Accuracy on assets flexibility	Accuracy between baseline value and power measurement when no dispatch.
KPI_24_Flexibility used for ancillary services and balancing	Depending on market set-up it is worthwhile to evaluate the required/activated flexibility of each System Operator through the bids and trades of FSPs
KPI_25_User satisfaction	The KPI will repeatedly measure the overall satisfaction (single-item) of users with the provided solutions at the demo sites and track it over time.
KPI_26_ Increase in RES hosting capacity	This indicator will measure how the optimal use of flexibility can increase the RES capacity in the distribution grid compared to a Business-As-Usual scenario, where the hosting capacity can be calculated using the existing established methodologies per pilot.
KPI_27_EV fleet baseline forecast accuracy	The indicator will measure the accuracy of baseline forecast for the EV fleet.
KPI_28_EV fleet flexibility forecast accuracy	The indicator will measure the accuracy of flexibility forecast for the EV fleet.
KPI_29_HEMS fleet baseline forecast accuracy	The indicator will measure the accuracy of baseline forecast for the HEMS fleet.
KPI_30_HEMS fleet flexibility forecast accuracy	The indicator will measure the accuracy of flexibility forecast for the HEMS fleet.
KPI_31_Algorithm latency/calculation time	Latency measures the time it takes for the optimal selection algorithm to respond to market requests or activate flexibility units. It assesses the algorithm's responsiveness, helping to ensure timely actions in the energy market.
KPI_32_Bid satisfaction rate	Market Bid Satisfaction Rate measures the percentage of successfully accepted market (simulated) bids by the optimal

	selection algorithm. It assesses the algorithm's effectiveness in fulfilling market demand, indicating its ability to efficiently allocate flexibility resources.
KPI_33_Topology detection F1	The F1 score is a metric commonly used in the field of machine learning and classification tasks, including Topology detection. In this context, the F1 score it assesses the accuracy of identifying correctly energized components within the distribution network.
KPI_34_ Non-Technical Losses Detection Rate	This indicator will measure the detection rate of non-technical losses in a dataset of smart meters acknowledged already by the DSO as fraudulent or not.
KPI_35_Fraud detection accuracy	This indicator will assure the accuracy of fraud detection algorithm within UC4.2. is above a certain threshold.
KPI_36_Fraud location detection error	One of the goals from UC4.2 is to determine a more precise location for the potential fraud. This indicator will measure the spatial resolution, by comparing the algorithm's result with the actual fraud location.
KPI_37_Fraud detection Costs-Benefit Ratio	Cost-Benefit Ratio (CBR) measures the economic feasibility of deploying an NTL detection model by considering both the costs associated with reparation or inspection costs (False Positives costs) and the benefits achieved from preventing or addressing non-technical losses (True Positives benefits).
KPI_38_Fraud detection F1	The F1 score is a metric commonly used in the field of machine learning and classification tasks, including Non-Technical Losses (NTL). In the context of NTL, the F1 score assesses the model's ability to correctly identify cases of fraudulent or unauthorized connections to the electrical grid, often associated with energy theft.
KPI_39_Accuracy of island detection	The indicator will measure the accuracy or the rate of success against false positive detections.
KPI_40_Detection of grid islands F1	The F1 score is a metric commonly used in the field of machine learning and classification tasks, including detection of grid islands. In this context, the F1 score assesses the model's ability to correctly identify when a specific line protection cuts off the power and creates a grid island.
KPI_41_Detection time	The indicator will measure the difference in time of the detection of the blown fuse by the algorithm and the time of detection from the real operative of the grid.
KPI_42_Electrical points detection	Distribution cables can suffer section changes along the line while supplying different clients. This means that a reduction of the section in certain parts of the grid will suppose a reduction on the capacity of the line and, thus, a potential risk of congestion in those parts of the line with lower section. This KPI is focusing in comparing the increase of congestions due to reduced section compared to the same line assuming there's no changes in section. It will be calculated as a percentage.

KPI_43_ Decrease in investment costs	This indicator will measure the investments costs decrease % in a planning scenario where the flexibility sources are optimized as well as the network investments, compared to a Business-As-Usual scenario, where the hosting RES penetration and network upgrades are calculated using the existing established methodologies per pilot.
KPI_44_Average amount of flexibility available from the energy community	This KPI measures the standard deviation of the flexibility available from the energy community in a specific time interval.
KPI_45_Average peak load reduction at the MV/LV transformer station	This KPI evaluates the effectiveness of the peak load reduction strategy on the secondary side of the MV/LV transformer, located upstream of the energy community under investigation. The objective is to verify the effectiveness of the flexibility offered by the energy community in reducing possible congestion at the local transformer substation. The KPI provides three key indicators to assess the impact of asset control, providing information on both the power reduction and the energy required to lower the peak.
KPI_46_Error in the prediction of electricity demand	The KPI measures the accuracy and reliability of forecasts of expected energy consumption, considering all delivery points in the energy community. It quantifies the difference between predicted electricity demand and actual electricity use. A lower percentage or error value indicates more accurate forecasts, while a higher error suggests less accurate forecasts.
KPI_47_Error in the prediction of photovoltaic production	The KPI measures the accuracy and reliability of forecasts of expected energy production, considering the photovoltaic systems installed in the energy community. It quantifies the difference between predicted energy production and actual production. A lower percentage or error value indicates more accurate forecasts, while a higher error suggests less accurate forecasts.
KPI_48_Flexibility activation accuracy	Flexibility is usually actuated on the base of a flexibility estimation or forecast. An important KPI is the quantification of how reliably a certain amount of flexibility can be activated.
KPI_49 Max flexibility prediction accuracy	To measure reliability of the flexibility estimation, we propose to use the mean relative absolute error between the observed and forecasted power profile of a group of controlled devices, when a control signal is delivered to all the flexible devices.

Table 2 - KPIs vs Use Cases

USE CASES	KPIs																																															
	KPI_1	KPI_2	KPI_3	KPI_4	KPI_5	KPI_6	KPI_7	KPI_8	KPI_9	KPI_10	KPI_11	KPI_12	KPI_13	KPI_14	KPI_15	KPI_16	KPI_17	KPI_18	KPI_19	KPI_20	KPI_21	KPI_22	KPI_23	KPI_24	KPI_25	KPI_26	KPI_27	KPI_28	KPI_29	KPI_30	KPI_31	KPI_32	KPI_33	KPI_34	KPI_35	KPI_36	KPI_37	KPI_38	KPI_39	KPI_40	KPI_41	KPI_42	KPI_43	KPI_44	KPI_45	KPI_46	KPI_47	KPI_48	KPI_49
HLUC1 - HORIZONTAL																																																	
UC 1.1 Short-term analysis of the impact of DER in the Distribution grid	■																																																
UC 1.2 Application of NILM for consumer's energy awareness		■																																															
UC 1.3 Utilization of deep learning for state estimation			■																																														
UC 1.4 Real-Time Thermal Rating (RTTR) for capacity calculation of MV lines				■	■														■																														
UC 1.5 Advanced Asset Management						■																																											
UC 1.6 Topology identification							■																																										
UC 1.7 Investment Deferral considering flexibility								■	■									■																															
UC 1.8 HEMS/BEMS DR optimization and local flexibility management										■	■	■	■	■	■																																		
UC 1.9 Initialization of HEMS/BEMS Demand Response strategy										■		■	■	■	■	■																																	
UC 1.10 Establishment of a flexibility market and flexibility procurement											■						■		■	■	■	■	■	■																									
HL-UC 2: GREECE																																																	
UC 2.1 Network planning for High RES penetration																					■					■																							
HL-UC 3: SLOVENIA																																																	
UC 3.1 Baseline and flexibility forecast for EV fleet																											■	■																					
UC 3.2 Baseline and flexibility forecast for HEMS fleet																													■	■																			
UC 3.3 Optimal selection of available flexibility																															■	■																	
HL-UC 4: SPAIN																																																	
UC 4.1 Topology detection																																	■																
UC 4.2 Fraud detection (non-technical losses)																																		■	■	■	■	■											
UC 4.3 Detection of unwanted or unexpected islands for PV panels																																							■	■	■								
UC 4.4 Detection of critical points in a electrical line																																										■							
UC 4.5 Improving the Grid Infrastructure																										■																	■						
HL-UC 5: SWITZERLAND																																																	
UC 5.1 Improve congestion management to facilitate DERs penetration																																												■	■	■	■	■	■
UC 5.2 Integrate flexibility with the distribution grid to provide balancing services																																												■	■	■	■	■	■

The OPENTUNITY KPIs will be also useful to check if the project is properly reaching OPENTUNITY Objectives.

Table 3 - KPIs vs Objectives

Category	KPIs																								
	KPI_1	KPI_2	KPI_3	KPI_4	KPI_5	KPI_6	KPI_7	KPI_8	KPI_9	KPI_10	KPI_11	KPI_12	KPI_13	KPI_14	KPI_15	KPI_16	KPI_17	KPI_18	KPI_19	KPI_20	KPI_21	KPI_22	KPI_23	KPI_24	KPI_25
SO1. Decarbonization of EU society	X	X		X	X			X	X																
SO2. Citizen and stakeholder empowerment		X								X	X	X	X	X	X	X				X	X	X			X
SO3. Ensure quality of supply in a context of increase of RES	X		X	X	X	X	X	X	X								X	X	X	X			X	X	

Category	KPIs																							
	KPI_26	KPI_27	KPI_28	KPI_29	KPI_30	KPI_31	KPI_32	KPI_33	KPI_34	KPI_35	KPI_36	KPI_37	KPI_38	KPI_39	KPI_40	KPI_41	KPI_42	KPI_43	KPI_44	KPI_45	KPI_46	KPI_47	KPI_48	KPI_49
SO1. Decarbonization of EU society	X																	X			X	X		
SO2. Citizen and stakeholder empowerment																			X		X			
SO3. Ensure quality of supply in a context of increase of RES	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

8 PILOT SITES ANALYSIS

8.1 GREEK PILOT SITE

8.1.1 INTRODUCTION

The Greek Demo site is placed in Mesogia, a suburb of Athens, in the region of Attiki. Moreover, Mesogia area is part of the Greek interconnected system and includes the municipalities of Koropi, Lavrio, N.Makri and the interconnected islands of Kea, Andros and Tinos. It is a semi-rural area that includes approximately 225,000 customers in its LV and MV networks, varied from households to small, medium, and large industries. The area benefits from installations of various forms of renewables, wind farms, and PV, including net metering and rooftop PVs as well. The location of Greek Demo is depicted in Figure 12.

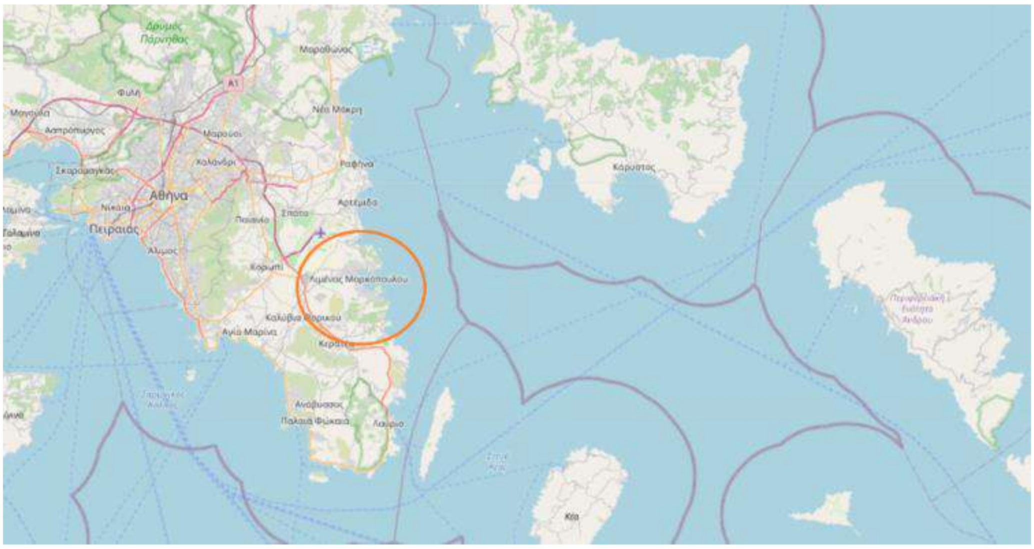


Figure 12. Greek Demo – Location of the Substation.

8.1.2 LOCATION DETAILS

Markopoulo Substation is located at the boundaries between the transmission and distribution system, transforming voltage from 150kV to 20kV level (Figure 13).

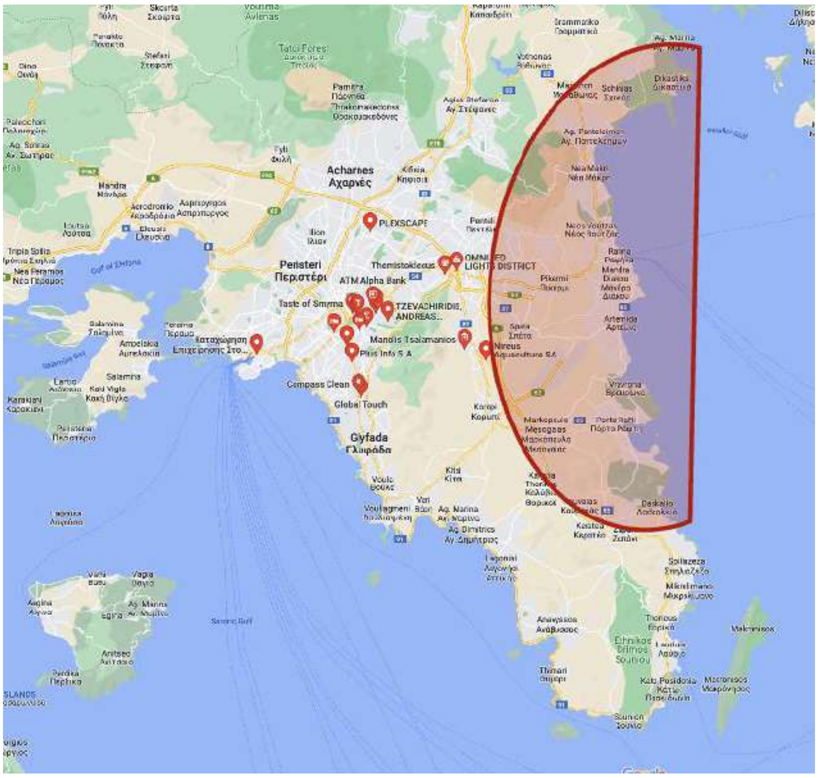


Figure 13. Greek Demo – Location of the Energy Distribution Network.

Three 150kV/20kV transformers of a rated apparent power of 40/50MVA are installed and fulfil the load of the connected consumers. Concerning RES penetration, there are 27.043 MW of PV plants connected to the Distribution Network. In addition, there are 20.7 MW of PV plants under approval for connection on the Distribution Network. There are no Wind farms connected to the Distribution Network.

On the MV side, a capacitor bank of 24MVar is utilized for voltage support. IPTO monitors and controls the HV (150kV) assets of Markopoulo Substation through the utilization of an EMS, and HEDNO monitors the MV side (20kV) through the usage of a DMS. Lastly, the single line diagram of the substation is depicted in Figure 14.

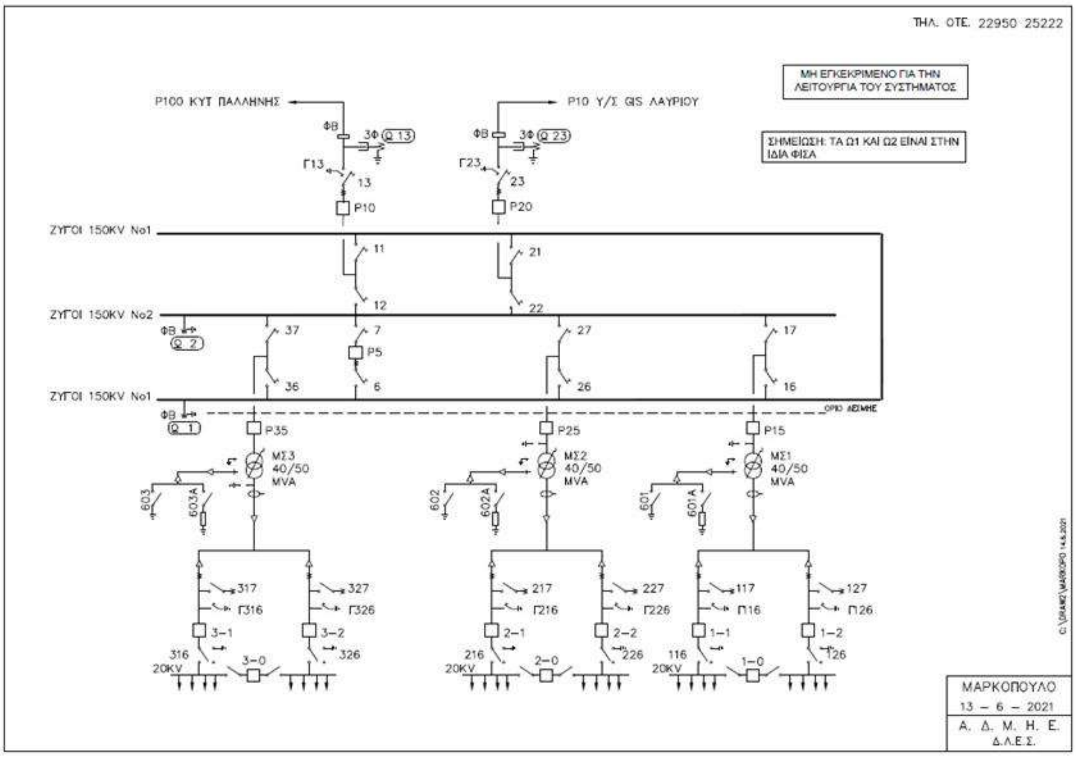


Figure 14. Single Diagram of the Markopoulo Substation.

8.1.3 PILOT INFRASTRUCTURE

Mesogia region consists of several connections including RES and EHV substations. The RES Substation is located in Polipotamos and is connected with Mesogia region through a double underwater cable (150kV). The first EHV Substation of Agios Stefanos is connected through a single-circuit HV overhead transmission line (150kV) and the second one, EHV Substation of Palini through a single-circuit HV overhead transmission line (150kV). 16 feeders in MV side.

The Markopoulo HV Substation serves the load of the area of Mesogia through three 150kV/20kV transformers of a rated apparent power of 40/50MVA. On the MV side, a capacitor bank of 24MVar is utilized for voltage support. Markopoulo HV substation is connected to the EHV substation of Pallini and to the Lavrio substation through 150kV overhead transmission lines. For observability and controllability purposes, the TSO monitors and controls the HV (150kV) assets of Markopoulo HV substation through the utilization of the EMS. The TSO monitors and controls the HV (150kV) assets of Markopoulo Substation through the utilization of an EMS, and the DSO monitors the MV side (20kV) through the usage of a DMS. Three SLAMs have been installed in three feeders as part of the Horizon 2020 project WiseGRID. The MV feeders connected to the Markopoulo substation are shown in Figure 15.

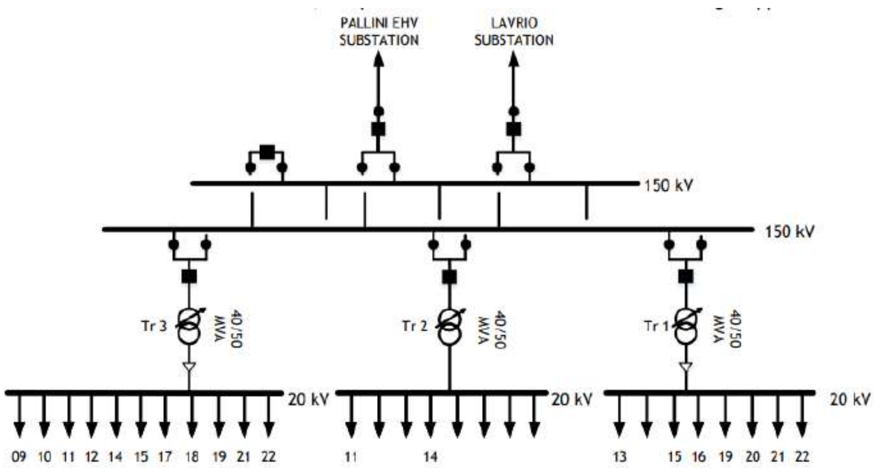


Figure 15. Greek Dem – Substation Transformers Schematics.

The electrical characteristics of the utilized transformers on the HV and MV sides are summarized in the Table 4 and Table 5 respectively.

Table 4. Electrical Characteristics of the Transformer on the HV Side of Markopoulo Substation.

Type	Value
Nominal Voltage	150 kV
Maximum Operating Voltage	170 kV
Number of phases	3
Number of conductors	3
Short Circuit level	31 kA
Basic Insulation level	750 kV (peak)
Power frequency withstand voltage (1 min)	325 kV rms
Nominal frequency	50 Hz
Variations of nominal frequency	± 0.2 Hz
Available auxiliary D.C supply voltage	110 V from batteries
Available auxiliary AC supply voltage	3- phase, 4 – conductors 230/ 400 V

Table 5.Electrical Characteristics of the Transformer on the MV Side of Markopoulo Substation.

Type	Value
Nominal Voltage	21 kV
Maximum Operating Voltage	24 kV
Number of phases	3
Number of conductors	3

Short Circuit level	10 kA
Basic Insulation level	145 kV (peak)
Power frequency withstand voltage (1 min)	50 kV rms
Nominal frequency	50 Hz
Method of grounding	Grounded neutral via ground resistor 12 Ω
Available auxiliary D.C supply voltage	110 V from batteries
Available auxiliary AC supply voltage	3- phase, 4 – conductors 230/ 400 V

The number and the type of the consumers fed by the substation considered in the OPENTUNITY project are shown in Table 6 below:

Table 6. Greek Demo – List of Consumers

	Latest Annual Network Data	
Customers	**Number**	**Unit**
Commercial buildings	2,812	no.
Residential buildings	123	no.
Costumers overall	**2.935**	**no.**

According to CEER in its last report about Quality of supply, Greece usually experiences (annually) 120 minutes of supply lost. The latest data about the network downtime and the network losses are presented in Table 7.

Table 7. Greek Demo – Grid Information.

	Latest Annual Network Downtime		
Latest Annual Network Losses (%)	**Cause of downtime**	**System Average Interruption Duration Index (SAIDI)**	**System Average Interruption Frequency Index (SAIFI)**
4.13%	Overloading, Environmental Conditions, Technical Faults…	1.56 hours	1.23%

8.1.4 PILOT TOOLS AND TECHNOLOGIES

8.1.4.1 SCADA

The pilot site includes a regional DMS. The role of the DMS is to monitor and supervise the HV/MV substation. The SCADA supervises the protection relays that are in the MV of the substation. The state of the relays is transmitted to the SCADA, based on the communication protocol IEC 870-5-103.

SCADA systems leverage the present telecommunications network to transfer tele-control signals, metering data, event signals, and alarm signals. The implemented connections between the components of the SCADA systems are briefly presented below:

1) Connection between the RTUs, which are situated in HV substations, and the CCS. This connection is made accessible by using either an ADSL connection or the E-NET telecom network, which is owned by the Hellenic Public Power Corporation.

2) Connection between the overhead MV lines installed tele-control switching components and the CCS. The switching components on the overhead lines are tele-controlled using GSM modems and the Telegyr TG800 communication protocol.

3) Connection between the CCS and the RTUs, which are installed for tele-control of urban MV substations.

4) Connection between the FPIs and the CCS. In multiple locations, FPIs comprise the required RTUs, which utilize an inbuilt GSM modem to send the fault signals using SMS messages.

8.1.4.2 AMI infrastructure description

HEDNO is responsible for setting up, operating, and maintaining the metering hardware required for the Distribution Network's seamless operation, often known as AMR or AMI (Figure 16). In order to achieve this, HEDNO obtains and validates metering data and provides the rightful electricity retailers with the measured consumption data required for consumer billing. HEDNO operates electronic meters that are capable to measure active and reactive power and send them to HEDNO's telemetering center.

Figure 16. Greek Demo – AMI Infrastructure.

8.1.4.3 Short Description of GIS Systems and operations supported.

The overall topology of the energy distribution network that is connected to the Markopoulo HV/MV substation, has been integrated into the HEDNO's GIS system. The integration of the Greek pilot's grid topology in the HEDNO GIS system provides highly accurate data on the positions of the various elements of the topology, such as the exact location of the network's consumers, pillars, substations, and switches, as well as the exact characteristics such as length, diameter, and type of conductor, and the location of the topology of the lines. The data provided by HEDNO's GIS system can be exported to multiple file types, especially to .csv, excel, kml, shape and GeoJSON and CIM.

8.1.5 DATA AND MEASUREMENTS

Other Databases and Systems

Data Management System: Regarding the DMS, it is responsible for the supervision of the HV/MV substations. Critical data are aggregated for the sustainable operation of the HV/MV substations such as event, fault alarms and metering data. Moreover, the system has the ability to supervise the protection relays of the MV subsystems by the use of the communication protocol IEC 870-5-103. Further options and services to be provided include among others, alarm management, topology information (with feeder traces and schematics), fault management, power flow and local allocators, outage management, quality indices monitoring and extraction, load shed, asset management, short-circuit analysis and a virtual environment fed with real grid details, such as study environment for investigating distribution feeder optimization, protection coordination and operator training simulation.

8.1.5.1 Homes/Buildings

The Greek pilot enables the HEDNO (DSO) and the IPTO (TSO) and therefore, home/buildings operators are not included. However, the pilot contains PV systems. Some information about the PV production is given below. However, new PV systems are integrated into the energy distribution network and therefore additional systems will be taken into consideration during the implementation of Greek Demo.

The pilot installation of the Greek demo consists of PV systems connected on both medium and low voltage sides of the Markopoulo network. The total installed power of the PVs in the area is 27.043 MW. The rated power of the PVs that are connected to the medium side voltage is 20 MW, while the other 7 MWs are referring to rooftop PVs.

Table 8. Greek Demo - PV Systems included in the Demo.

HV/MV transformer	ID of the feeder	Power of PV plants (MW)
1	13	0.88
	15	2.07
	16	0.85
	19	3.96
	20	0.32
	21	0.68
	22	3.65
2	11	0.75
	14	0.73
3	09	1.49
	10	0.65
	11	0.86
	12	0.61
	14	0.76
	15	2.32
	17	0.27
	18	2.61
	19	2.14
	21	1.1

8.1.5.1 Smart Metering

The Markopoulo substation serves 123 MV customers and about 2812 LV customers. All the MV customers and a limited number of LV customers are equipped with smart electronic meters. Those smart meters are allocated to the feeders that are connected to the three transformers of the Markopoulo substation. HEDNO is equipped with a dedicated AMI.

HEDNO operates a meter data management system, which is responsible for the measurements that are collected from the distributed smart meters. The system analyses, processes, validates and stores the metering data.

Currently, the AMR communicates with each Smart Meter once every 24 hours using GPRS to collect metering data and meter log files. Up till now, all MV customers are equipped with Electronic Telemetering Meters, but most LV customers are equipped with electromechanical meters which measure active and in certain cases reactive energy consumption. For electromechanical meters, metering data is manually logged by DSO technical personnel.

The measured powers from electronic meters are being recorded at 15-minute intervals and are transferred to the telemetering center every hour. In the Mesogia region all MV clients are equipped with electronic meters while several number of LV clients are equipped with. HEDNO has began an initiative for the upgrade of current meter systems into smart devices. The initiative involves deploying 3.12 million smart electricity meters and establishing the essential supporting infrastructure in Greece between 2023 and 2026.

8.1.6 BARRIERS AND CHALLENGES

Table 9 highlights the potential obstacles and risks of the Greek pilot site, with a focus on Greek Demo's anticipated tasks on the OPENTUNITY project. Each criticality indicates the level of likelihood and impact, ranging from low to high, as well as a possible solution envisioned.

Table 9. Greek Demo – Criticalities log

Description of criticality	Likelihood	Impact	Ways to address criticalities
Lack of Regulations for the integration of the technologies into the Demo Site	LOW	MEDIUM	Actively engaging with the departments of the demo participants in order to integrate the technologies into the power system based on the existing regulations.
Technical Challenges about the integration of OPENTUNITY's technologies into the Greek Demo.	MEDIUM	MEDIUM	Assure the technical understanding of the associated team and the collaboration within the departments of the Demo participants, as well as the corresponding technical partners. As a worst-case scenario simulation based on real data, will be enabled in order to test and evaluate the technologies.
Economic Challenges for the implementation of the project's technologies into the Greek Demo.	MEDIUM	MEDIUM	Review the project's costs and optimize the spending. In line with the technical partners lower cost solutions will be examined.

Data Acquisition Challenges	MEDIUM	HIGH	Establish a strong collaboration with the data providers within the different departments among the demo participants. Ensure the accuracy as well as the consistency of the acquired datasets and prioritize their safety.

8.2 SLOVENIAN PILOT SITE

The Slovenian pilot will consist of parts of the distribution system network belonging to two Slovenian DSOs: Elektro Ljubljana (EL) and Elektro Primorska (EP).

8.2.1 INTRODUCTION

8.2.1.1 Elektro Primorska (EP)

Elektro Primorska d.d. (EP) is one of five Slovenian power distribution companies (DSO). It covers an integral part of the electricity system of the Republic of Slovenia, supplying the area in the SW, W and NW part of Slovenia and covering 4,335 km2 or approximately 22% of the total country surface. EP is supplying energy to both the lowest, deepest, and highest points in Slovenia: from Adriatic Sea to Postojna Cave and Kanin at an altitude of 2.220 m above sea level. EP supplies around 136.704 end-consumers, with yearly consumption of 1,6 TWh and peak demand of 300 MW. In the last decade the number of connected distributed energy resources (DER) has increased significantly and reached more than 130 MW of installed power, mainly from photovoltaics and small hydro plants. There are currently 117.000 end-users connected to AMS, available for remote consumption data analysis. The company possesses a well-defined vision and strategy for advancing the creation of smart grids and facilitating the efficient, dependable, and sustainable functioning of the distribution network. EP's core mission is to deliver electricity supply of high quality and reliability, while adhering to environmental and safety standards mandated by relevant laws and regulations. Additionally, the company aims to develop and construct an electricity network that caters to the requirements of both business and household customers. By operating professionally and efficiently, EP strives to fulfill the expectations of its owners and other stakeholders.

8.2.1.2 Elektro Ljubljana (EL)

Elektro Ljubljana, d.d. (EL) manages the largest electricity distribution network in Slovenia, covering over 6,166 km2 in the central part of Slovenia, which represents around 30% of the total area of Slovenia. It is supplying 348,447 end users (data from the end of 2021), with 261,001 metering points in the remote metering control system. The number of electricity producers connected to the EL network is 723. EL distributes around 37% of the electrical energy, consumed in Slovenia. 27.3% of the end-users are households, while industrial consumers represent 72.7% - 64.8% of these are connected to the MV network and 35.2% to the LV network.

8.2.2LOCATION DETAILS

8.2.2.1 Elektro Primorska (EP)

One of the pilot sites will be the industrial park (shown on Figure 17) in the town of Ajdovščina, which is located in the SW of Slovenia (pictured in Figure 18) and is a part of the distribution system belonging to Elektro Primorska.

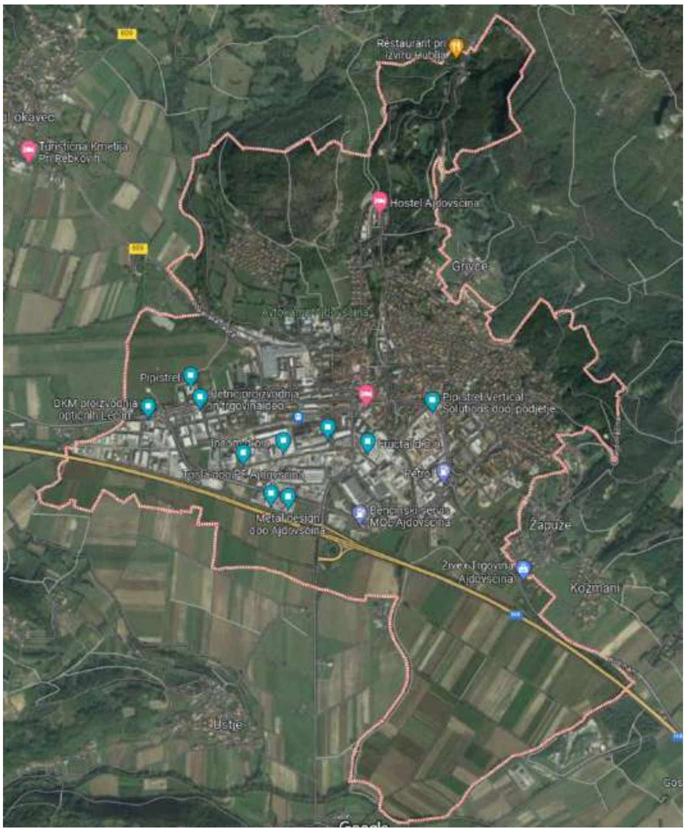


Figure 17. The city of Ajdovščina (EP)

Figure 18. Industrial Park Ajdovščina

Reduxi will be installed in several locations in the companies within the industrial park Ajdovščina. Industrial Park Ajdovščina is already a pilot site of the Horizon Europe project STREAM and in the scope of this project, 13 companies in the area have already signed letters of intent. Since three partners (Elektro Primorska, Kolektor sETup and AVANTCAR) are partners in both STREAM and OPENTUNITY, synergies could be used and Reduxi could provide the optimal solution for the energy management system of the companies and connection to the aggregator (Kolektor sETup).

In the scope of the analysis, we will identify companies, which could benefit from installing Reduxi. The exact list of the proposed locations will be provided at the later stages of the project. Within companies we will connect to the Reduxi solar power plants, electric vehicle charging stations, battery energy storage systems, HVAC, and billing meters. Reduxi will provide control of connected devices.

8.2.2.2 Elektro Ljubljana (EL)

EL will use the part of the grid, compromising MV feeders and LV network, for which the testing of use cases would be most beneficial. The site will involve grid assets and MV/LV transformer stations, which are already equipped with sensors and smart meters, so they will be able to provide data close to real-time. When decided EL will prepare an export of topology of the preselected part of the grid in a CIM format.

The pilot site will include a 110/20 kV substation Grosuplje and one of its 20 kV feeders J28 DV Polica, which was experiencing a lot of outages in the past years (especially high SAIFI and SAIDI compared to other substations). This feeder has a number of 20/0,4 kV substations, but for the scope of the project 10 most suitable substations were chosen, shown in the list below:

- VRH PRI LESKOVCU 20/0.4 G-389
- SPODNJE BREZOVO 20/0.4 G-311

- POLICA-PEČ 21/0.42 G-260
- STARA VAS 20/0.4 G-319
- PEČ 20/0.4 G-233
- DEDNI DOL 20/0.4 G-031
- ŽABJA VAS 20/0,42 G-407
- DOLE PRI PANCAH 20/0,42 G-044
- PEROVA VAS 21/0.4 G-219
- VELIKO MLAČEVO20/0.4 G-370

All of the substations have exactly one transformer and were already equipped with MT880 smart meters. Selected distribution transformer substations are located at the vicinity of town Grosuplje with the nearest meteorological station Grosuplje. Low voltage network in city Grosuplje is mostly underground, while the medium voltage network in the centre of town is underground and mostly above ground in the surroundings, as shown in Figure 19.

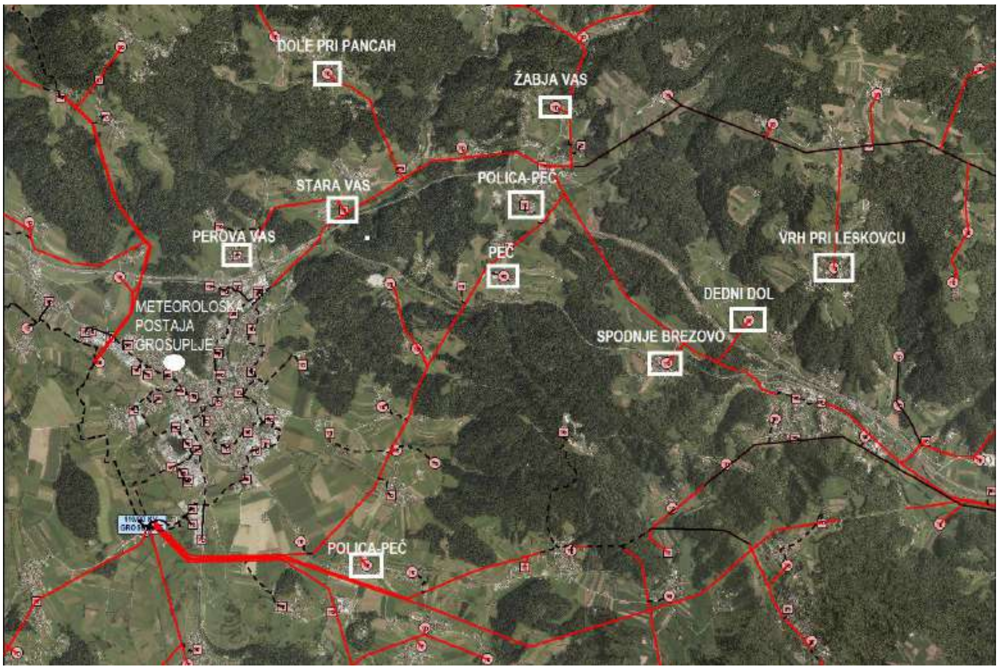


Figure 19. EL – pilot site air view.

Selected distribution transformer stations are located on J28 DV 20KV Polica feeder, which is a rural type of feeder. Feeder contains:

- 38 distribution transformer stations and
- 1,225 active measuring points:
  - 1.182 measuring points of consumption,
  - 36 measuring points of self-production,
  - 7 measuring points of production

In addition to the infrastructure of the two DSOs mentioned, an EV fleet and charging stations, which are owned by AVANTCAR will be used in the testing of OPENTUNITY solutions.

8.2.3 PILOT INFRASTRUCTURE

8.2.3.1 Elektro Primorska (EP)

The total length of the EP network at the different voltage levels is shown at Table 10.

Table 10. EP – Network Length.

Network length (km)	Overhead	Underground	Total length
HV (110 kV) infrastructure	57	0	57
MV (20 kV) infrastructure	1,974	655	2,629
LV (0,4 kV) infrastructure	2,819	1,802	4,621

EP distribution network has 5 voltage levels, which include power lines and utilities at HV (110 kV), MV (10 kV, 20 kV and 35 kV which is phased out) and LV (0.4 kV (230 V / 400V) and 1 kV). According to the latest annual network data HV facilities include 2 DTSs 110/35 kV and 29 DTSs 110/20/10 kV. Also, 4 DTSs 35/20/10 kV, 26 DSs 35,20,10/ 35,20,10 kV and 2480 TSs compose the MV facilities.

The number and the type of customers served by the EP are listed in Table 11.

Table 11. EP – Number of Consumers.

	Latest Annual Network Data	
Customers	**Number**	**Unit**
Business consumers	18,687	no.
Residential consumers	117,596	no.
Consumers overall	136,283	no.
Prosumers	421	no.
Costumers overall	**136,704**	**no.**

Finally, the essential data about indicators "SAIDI" and "SAIFI", which constitute the two fundamental metrics of network reliability, is assembled in Table 12.

Table 12. EP – Grid Information.

		Latest Annual Network Downtime		
Latest Annual Peak Demand (MW)	**Latest Annual Network Losses (%)**	**Cause of downtime**	**System Average Interruption Duration Index (SAIDI)**	**System Average Interruption Frequency Index (SAIFI)**
302.2	4.2	Unplanned interruptions	3.22	2.69

Higher force

Foreign cause

Own cause

...

8.2.3.2 Elektro Ljubljana (EL)

The total length of the EP network at the different voltage levels is shown at Table 13.

Table 13. EL – Network Length.

Network length (km)	Overhead	Underground	Total length
HV (110 kV) infrastructure	365	12	377
MV (20 kV) infrastructure	3,286	2,525	5,811
LV (0,4 kV) infrastructure	4,719	6,496	11,215

According to the latest annual network data HV facilities include 3 DTSs 110/35 kV and 25 DTSs 110/20/10 kV. Also, 1 DTS 35/20/10 kV, 26 DSs 35,20,10/ 35,20,10 kV and 5511 TSs compose the MV facilities.

The number and the type of customers served by the EP are listed in Table 14.

Table 14. EL – Number of Consumers.

	Latest Annual Network Data	
Customers	**Number**	**Unit**
Business consumers	253,320	no.
Residential consumers	95,126	no.
Consumers overall	348,447	no.
Prosumers	723	no.
Costumers overall	**349,170**	**no.**

Finally, the essential data about indicators "SAIDI" and "SAIFI", which constitute the two fundamental metrics of network reliability, is assembled in Table 15.

Table 15. EL – Grid Information.

Latest Annual Network Downtime		
Cause of downtime	**System Average Interruption**	**System Average Interruption**

	Duration Index (SAIDI)	Frequency Index (SAIFI)
Unplanned interruptions **Higher force** **Foreign cause** **Own cause** **...**	72.06 min	1.82%

8.2.4 PILOT TOOLS AND TECHNOLOGIES

8.2.4.1 Elektro Primorska (EP)

8.2.4.1.1. SCADA

EP uses SCADA Network Manager 5.5 together with the OMS system by ABB, which was updated in 2012-2013, but will require a comprehensive technological and functional upgrade in the near future.

8.2.4.1.2. AMI infrastructure description

The HES system is used to collect measurement data from all meters on the costumer side and meters at points of contact with the transmission system. Meter reading takes place via the GPRS network and concentrators in transformer stations.

HES is also connected to GIS for graphical display of all measuring points. The current HES software consists of two systems, L&G Advance 8 on Microsoft technology for older installations and ePoint on the Lynux platform for all new meters. The short-term plan is for ePoint to take over as the sole HES software.

The GIS system standard network visualization functions are used by a wider range of EP users. In addition, it currently represents the best possible approximation of the network data model and is also used to transfer customer data to the SCADA/OMS system, with the aim of establishing a precise connection between the customer and the LV connections from TS 10 (20)/0,4 kV. GIS is also tightly integrated with the Maximo asset management and maintenance system. GIS also uses the OMS system for planning network outages, data of which is transferred to the Maximo system, from which the necessary notifications are sent to all customers.

In EP, it is used the GIS platform by ESRI, which is upgraded with the "UT Electricity" by AED SiCAD. In addition to the visualisation and modelling of the network, GIS represents the entry point in the EP and at the same time the basic technical data repository. They are or will continue to exchange, through integration or standardized protocols, with other business and technical systems such as Maximo, SCADA, DMC, GREDOS, SCALAR. A data model in the GIS system and the possibility of exporting the network in the format specified by CIM standard is designed accordingly. GIS has the functionality of generating single pole/operating schemes, taking into account the topology of the network. At present, full integration is carried out only with the Maximo system, while the data in other systems is updated manually.

Currently, the network topology is in three systems, which in most cases overlap: SCADA, GIS and ERP/eIS. SCADA defines the topology for the HV and MV network. GIS defines the topology for the LV network, and the part for HV and MV can be taken from the SCADA system. The topology of the LV network changes very little over time, as there is no redundancy in the power supply. The ERP or eIS itself defines the connection (topology) of the customers with the location of the connection in the LV or MV network. The availability of each part is presented in Table 16.

Table 16. EP – Network Topology Identification.

Voltage level	Availability of topology (%)
HV	100
MV	100
LV	30
Buyers	30

8.2.4.2 Elektro Ljubljana (EL)

8.2.4.2.1. SCADA

The distribution network of EL has long been unobservable, but in recent years, after the introduction of the SCADA ADMS management system, EL has obtained a modern SE. The SE is among the fundamental ADMS functions and is a prerequisite for the successful execution of the remaining network operation, optimization, analysis, development, testing, and training functions. The SE is used to observe the conditions in the DN, utilizing available real-time measurements and calculating state variables - voltage indicators and power flows - based on past and current telemetry data. Several advanced features of ADMS in the new dispatch center are based on the automation of the MV network.

8.2.4.2.2. Short Description of GIS Systems and operations supported.

GIS at operational level is used for administrative and catalogue support for the inputs at SCADA ADMS. GIS is classified as a technical system, and it is standalone application named PISELJ. This app has a variety of options and GIS is updated daily. CIM/XML adapter and GIS importer are used for model import and validation. The model is updated daily with the changes overwritten as per the updates imputed in GIS model. The overall structure of the model is shown on Figure 20.

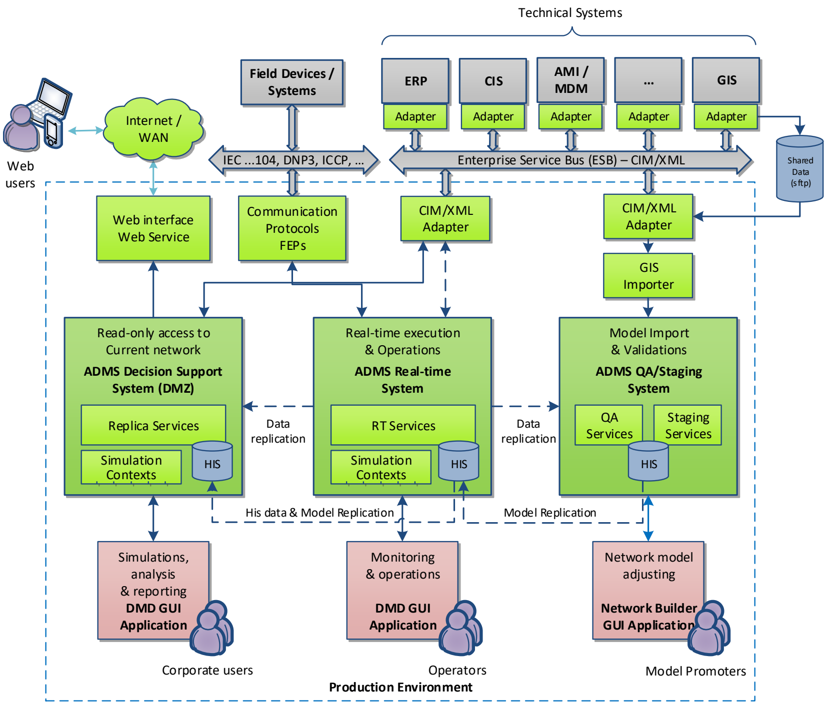


Figure 20. EL – ADMS High Level view.

The topology is then used for multiple purposes and available to dispatch. It can be colored by energization, voltage level, phases, circuits, abnormal operation, by feeder etc as shown on Figure 21.

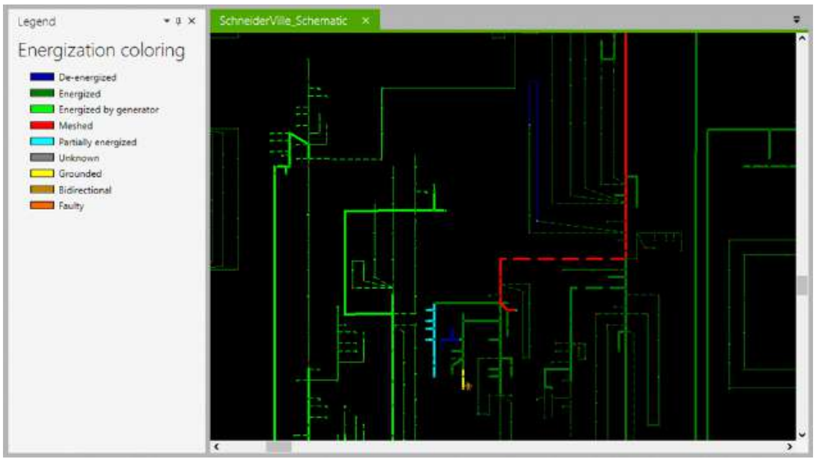


Figure 21. EL – Network Topology Colorization.

The availability of the topology is fully on hand and can be seen up to the final user on LV. The network tree according to the topology is created as shown on Figure 22.

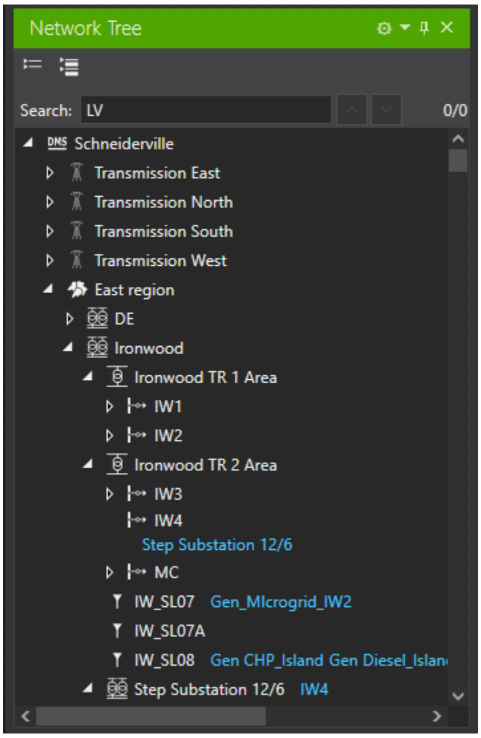


Figure 22. EL – Network Tree creation.

Basic algorithm for the topology analysis algorithm without the parallel sources is shown in Figure 23.

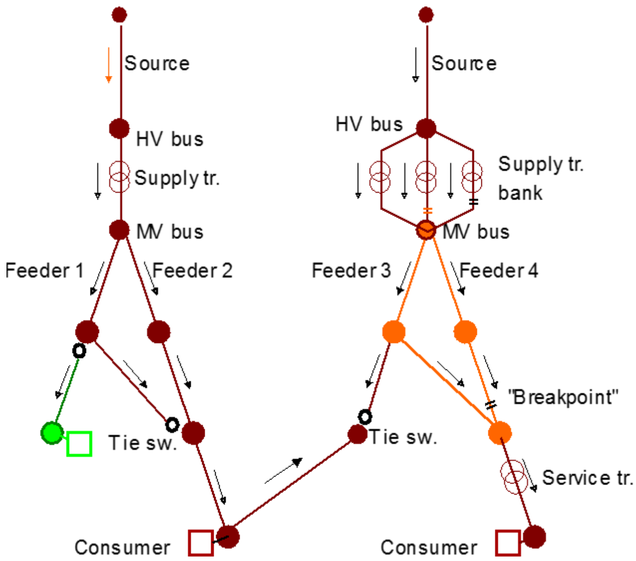


Figure 23. EL – Topology Analysis Algorithm Without Parallel Sources.

In the first step of the basic algorithm, scanning starts from an energized energy source and its attached node (typically a HV bus). By default, the energy source is presumed to be energized, but it can be changed if it has the "SourceStatus" signal attached, or if it is supplied from the transmission network modelled in the ADMS.

The algorithm then processes all the branches connected directly or by closed switches to the considered node and adds the opposite node of that branch to the queue of the nodes to process. Each traversed branch and node are marked as such. The process is recursively continued until all the branches and nodes in the tree have been detected, i.e. the queue becomes empty. Scanning is done using the "breadth first" approach, i.e. nodes of the same topological distance from the source are processed in the same sweep If the network is fully radial, no node or branch will be encountered twice. If the loops within the tree exist, as on the right side of the network shown in Figure 23, at one point the algorithm detects that the node at the opposite end has already been traversed. The branch on which that occurred is marked as a "breakpoint" and it is stored for a later analysis; the node is not traversed twice. Marking of the traversal is done per each phase separately. For example, traversing a bank of three single-phase transformers (as in Figure above) will produce three separate per-phase marks on the secondary MV bus. Such a bus is not marked as the breakpoint, as it does not form a true electrical loop. Provisions in the algorithm exist to properly handle the situations when such single-phase pseudo-loops span over multiple branches.

The first step is complete after all the trees have been processed. As a result, all the traversed branches and nodes are marked as fully (as indicated in dark red in Figure 23) or partially energized (depending on the traversed phases), and their topological direction is determined, as indicated by the arrows. The circuit hierarchy is determined according to the rules outlined above. While building the network graph, the child elements inherit the appropriate attributes (e.g., energization status, phasing information, feeder and transformer area which the element belongs to) from their parent elements.

In the second step, the loop marking is performed. From the recorded "breakpoint" branches, tracing up is performed on both sides, until the two traces meet. The end result presents the topological loop, marked orange in Figure 23

In the third step, the de-energized parts of the network are identified and traversed. During the first step, all open switches encountered as the neighbors of the energized network have been recorded in a temporary list, along with both their ends. If the opposite end has not been visited in this batch, and it does not belong to the tree known to be unaffected, it means that it is de-energized. The de-energized islands are traversed in a similar manner as the energized part, and their elements are marked as de-energized. If a faulted element or a grounding is encountered during this scan, the island is marked as "faulted" or "grounded" as appropriate. An island may also span the partially energized elements. This step is repeated recursively, processing the islands from the tie switches by separating the de-energized parts until there are no more tie switches to process; this ensures that all de-energized islands are processed. Additionally, the network parts which are not connected anywhere are detected, and the island processing is performed on them as well, starting from the randomly selected element within them.

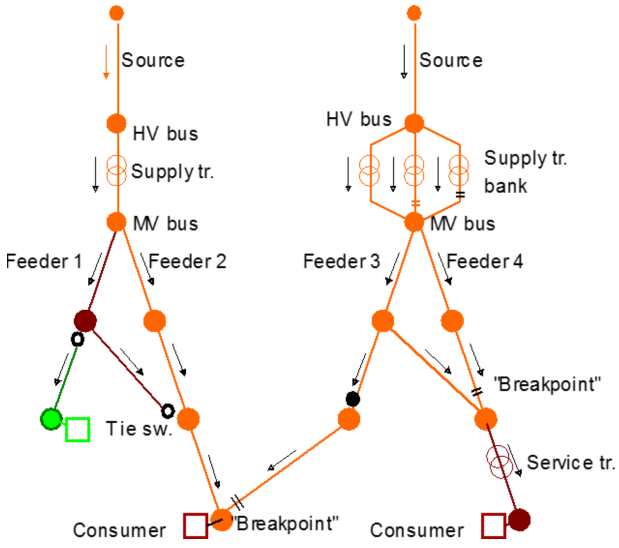


Figure 24. EL – The illustration of Topology Analysis algorithm with parallel sources.

In case that the parallels between the energy sources exist (Figure 24), it is detected during the first phase: when the algorithm starts from one source, it will reach the other one. In that case, those sources are marked as parallel, and the scanning is eventually restarted (there is a strategy how to deal with multiple parallel sources). After the restart, the scanning begins from all parallel sources simultaneously (as if they are connected to the same point on the HV end), and there is a single resulting tree. For each loop detected, a "breakpoint" branch will be generated at the point furthest from the sources, and the resulting contour marked as meshed (orange).

8.2.5 DATA AND MEASUREMENTS

8.2.5.1 Elektro Primorska (EP)

Data collected, stored, and processed.

The most important system is the SCADA system, which provides operators with an overview of the entire network that they supervise and control.

Measurement of operating variables such as voltages, currents, power and efficiency factor at the HV level is carried out by field computers. They get the voltage from the NMT measuring winding and the current from the TMT measuring core. Protective functions at the 110 kV level are performed by protective relays that receive voltage from the protective winding NMT and current from the protective core TMT. Protective relays carry out switching manipulations of circuit breakers in case of short and ground circuits, overvoltage, overload, etc.

At MV level in RTP and RP, operational measurements and protective functions are performed by protective relays. These measure operating variables for operators in DCVs and also protect power equipment from hazardous operating conditions by controlling circuit breakers. Protective relays on the MV level get voltages from the protective winding of the NMT and currents from the protective core of the TMT.

SCADA receives operating measurements from remotely controlled objects (RTP, RP and TP). An RTU device is installed in RTP and RP, which collects all measurements of remotely controlled devices at the facility level and sends the information to SCADA. In the DCV (remote control center), where the SCADA is installed, operators monitor the operation of the system: voltages in nodes, currents on feeders, power flows, monitor and perform switch manipulations, voltage regulation, network configuration, etc.

The data acquisition system connects the control center to the substation or local control equipment. RTUs and SASs collect data from the power system. Data is transmitted to the servers in the control center via dedicated communication lines, for instance, radio links, power line carriers, optical fiber, etc. RTU communicate with the SCADA Application server via communication lines connected to one or more PCUs. The PCU consists of the PCU Server and the Communication Module. Both the PCU Server and the Communication Module can operate in a redundant configuration. The Communication Module (RCM or serial communication port devices) is the physical interface to the external communication links such as modems or other communication equipment.

The data collected from the RTUs by the PCUs is sent to the RCS module in the SCADA Application server. The RCS normalizes the data by converting the indication values to standard representation (OPEN, CLOSE, TRANSITION and INVALID) and converting the measured and accumulator values to engineering units. The PCUs and RCS module in the SCADA Application server form the data acquisition system.

The data acquisition system:

- Supports a variety of RTU protocols. This allows for integration of both existing and new RTUs from a number of suppliers.
- Supports integration of substation automation systems.
- Provides a robust and flexible data acquisition, which can recover from multiple failures as long as the minimum number of critical components is available.
- Provides a suite of efficient tools for maintenance, reconfiguration and expansion of the data acquisition system itself.

Data Processing is the handling of the power system data in the SCADA Application Servers. This data can be acquired, manually entered, or produced by another application. The data processing deals with the following items: Measurands, Indications, Accumulators (Pulse Counters), Data Quality, Secondary Source Data (Redundant Data Values) and Composite objects (Refer to "Redundant Data Values" Section)

The DMC is located at the location of RTP (distribution transformer station) Gorica in Kromberk. It ensures smooth and reliable operation of the distribution power system 24 hours a day, 7 days a week and 365 days a year. It has two job positions with the same hardware (each with four monitors) and a wall-mounted display (3 monitors).

Existing SCADA ABB NetworkManager ver. 5.5 is the product of the Swedish ABB manufacturer and is installed on HP Blade 460 G7 servers with the Linux RetHat 5 operating system and the Oracle relational database. The system is designed redundantly as "warm reserve" (SCADA and UDW). Figure 25 shows the status of an existing system.

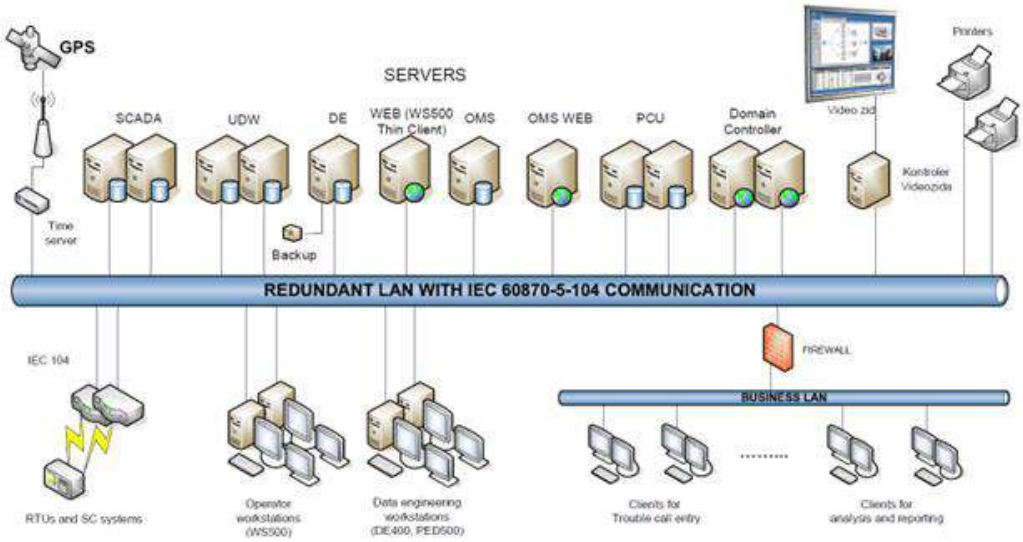


Figure 25. EP – Communication Protocol.

The used communication protocols are IEC104, IEC101 and DNP3 for RTU communications and ICCP for external control system communications.

Other Databases and Systems

Short Description of EMS or DMS and operations served.

EP has only SCADA at the moment. The plan for a DMS is in the next few years.

Brief information about Remote Terminal Units – RTUs

The SCADA system is connected to the RTUs via a communication infrastructure within the hardware system. The process database must allow the exchange of process information with electricity facilities:

- Distribution transformer stations, distribution stations, transformer stations, HV, MV and LV networks.
- Dispersed production sources of electricity.
- With adjacent management centres (distribution centres in Slovenia, the transmission management centre - ELES).
- With external partners and third-party software packages.

Short Description of failures databases and operations served.

The purpose of Outbreak Management System is to effectively manage and eliminate network outages in such a way that network users experience as little interruption as possible for as little time as possible. In this case, we can talk about reliable network operation. Therefore, the Outbreak Management System must have at least the following data:

- About the current state of security elements operation (relays, circuit breakers, protection devices, fuses) of circuit breakers and other switches in the network
- Topological network data with the state of switches that affect the change of topology
- The data from the metering points of the network users

Based on this data, the indicators of quality of supply (SAIDI, SAIFI) can be calculated on the network and with consumers.

The system for reporting and processing faults in the network will assist the personnel of the appropriate service in recording telephone calls from consumers in the event of power interruptions or other issues related to the supply of electricity and the preparation of responses. The information generated this way will then be used in responding to calls, informing the field crews and other necessary activities in remedying faults. The fault logging and processing system will use data from consumers databases and DEES.

8.2.5.1.1. Homes/Buildings

On pilot sites OPENTUNITY will install Reduxi HEMS which will control production and consumption of electricity locally. Reduxi will enhance the connectivity to aggregators and establish the connection to grid operator. This will enable new tariff designs and provision of flexibility products that could be used for different purposes like trading on flexibility market or provision of upcoming DSO ancillary services.

Reduxi provides algorithms, communication, and actuation protocols to bring innovative energy management and optimization models to the residential sector. Reduxi connects directly to the solar power plant inverters, battery energy storage systems, heating, ventilation, air conditioning systems (HVAC), EVCS, and electricity billing meter of DSO, using their communication protocol interface or API's (shown on Figure 26).

Figure 26. Reduxi connections.

Reduxi controls/manages the production and consumption of electricity. Instead of the end customer, Reduxi automatically selects the cheapest way of using electricity and strives for maximum self-sufficiency. The device itself is, in principle, intended for households, but it can also be used for building or charging point operators (CPO or eMSP), industry or system integrators (shown in Figure 27).

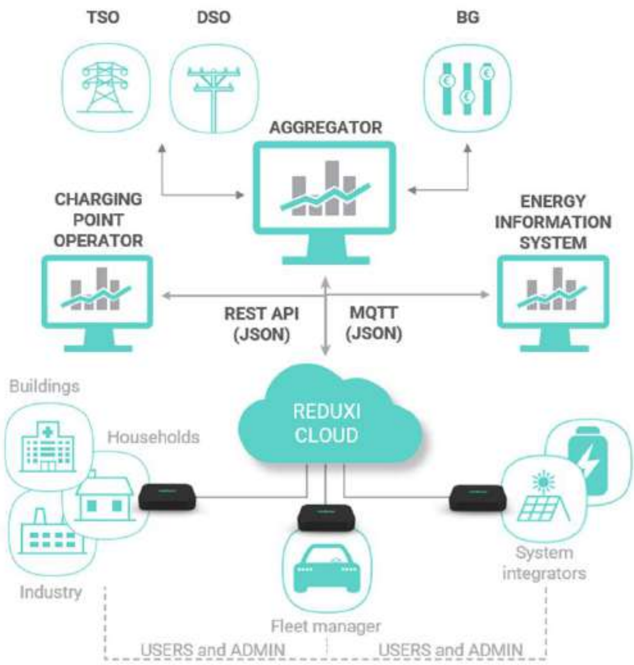


Figure 27. Reduxi usage examples and connectivity to aggregator.

At this time, the number of companies which will install Reduxi HEMS is not clear, therefore we can't provide more details about the buildings. For those that will choose to install it, their devices, such as PV, HVAC devices, EV charging stations and battery energy storage systems will be connected to the Reduxi. These devices support communication with 3rd party systems like Reduxi (Figure 28) where they have available TCP/IP or serial RS485 physical communication with Modbus, M-Bus, OCPP, or similar protocols.

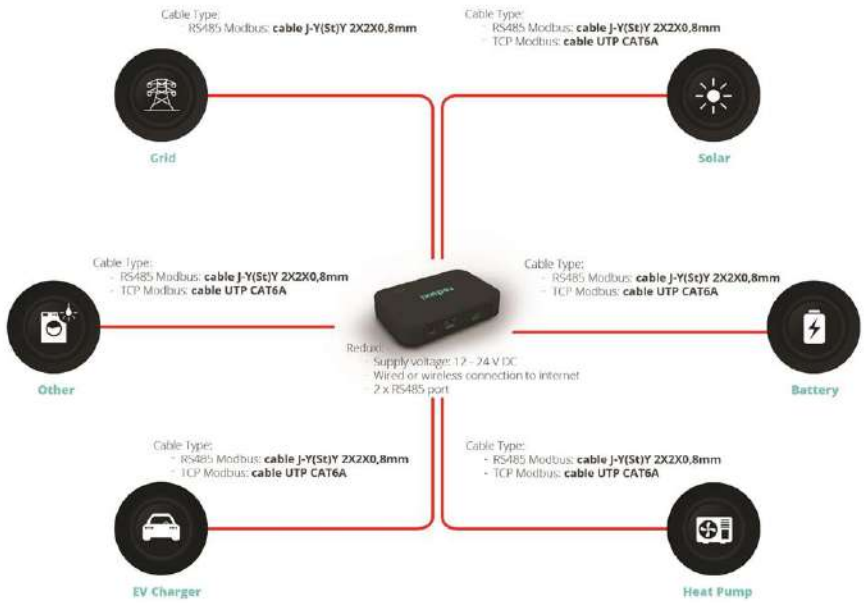


Figure 28. Connectivity to the Reduxi device.

8.2.5.1.2. Smart Metering

About 117.000 out of 136.000 costumers have been equipped with smart meters so far. The plan is to cover all of them till the end of 2023.

Data collection (frequency) and storage

The frequency of collection varies depending on the purpose of the meter, from once a day to every 15 minutes.

Measurement data is collected by systems for monitoring conditions in the network, such as the SCADA system and various measurement systems. Measurement data is needed to assess the current state of each asset and to control each operational decision. The measurements are also used for network planning and to predict future consumption trends and network conditions.

Measurement data partitioned into the following groups:

- Real-time data
  - U, I, P, Q, cos fi, f, meteorological, …
- Periodic data
  - Energy, P, Q
  - Energy quality: sags, harmonics, flickers, …
- Historical data
  - Averages: 15 minutes, hourly data, daily data
  - Profiles: Consumption curve (customers), RES

Connectivity and data transmission

The Measuring Centre contains a central database of measurement data from all electronic (system) counters of the received and transmitted electricity and control counter measurements.

Received/delivered active (P) and reactive (Q) power is measured at users (consumers, producers), connected to the distribution network and at the intersections of the transmission and distribution network in the distribution transformer station (usually on the HV side of the transformer field). The purpose of the Measuring Centre is to unify the gathering of the calculation measuring counter data and to manage various electronic power counters.

The Landys-Gyr system Advance is a basic management app at the Measurement Centre collecting remote-read data in SQL database from:

- Electronic industrial counters of received/delivered measurements from the transmission network

- in distribution transformer station (directly via optical or xDSL network)

- Electronic industrial counters of consumers with a limiter of a current that is greater than 3x63A (directly via mobile GPRS network, via xDSL network, via PSTN network or in combination with a mobile GRPS network or xDSL network in conjunction with PLC communication)

- Electronic household counters of consumers with a limiter of a current that is smaller than 3x63A (directly via mobile GPRS network or in combination of mobile GRPS network or xDSL network in conjunction with PLC communication)

- Electronic industrial counter in transformer stations for the purposes of control measurements (via GPRS network, a PLC data concentrator is used as a communication gateway)

The Advance system allows partial parameterization, such as setting the time and wider management of the counter data, such as creation of the load diagram of the measuring point and recording of events on the counters. If the counter has a circuit breaker installed, we can remotely deactivate and/or enable re-activation of the network user.

Processes in the Advance system are well defined, there are no systemic problems in their implementation. The Measurement Centre is well connected to the eIS due to the Advance system for the purpose of calculating electricity, but there's a lack of connection of data and technical systems to support operating and planning, such as GIS, SCADA, Gredos, OMS for the needs of analyses of planning and operating, as well as reliability. Integration with GIS is being prepared - only control measurements in the first phase.

Standards supported

When planning, implementing, and achieving equipment characteristics, the following standards must be used:

- SIST – Slovenian Standards
- IEC – International Electrotechnical Commission
- ISO – International Organisation for Standardisation
- EN – European Norms

Other standards can be used as well:

- DIN – German Industrial Standards,
- BSI – British Standards Institution,
- ANSI – American National Standards Institute,
- ITU – International Advisory Board on telephony and telegraphics, and
- VDE – German Electrotechnical Commission,
- IEEE – Institute of Electrical and Electronics Engineers,
- NEMA – National Electrical Manufacturers Association

8.2.5.2 Elektro Ljubljana (EL)

Data collected, stored, and processed.

SCADA systems collect a wide range of data points, including power, voltage, currents, and other parameters that are critical to the operation of power network. This data is typically collected in real-time and stored in a centralized database, where it can be processed and analysed to identify trends and patterns, and other anomalies in the outage events. SCADA systems also incorporate machine learning algorithms and other advanced analytics tools to predict future trends and detect anomalies in the data. In this case, machine learning is used to forecast on near term a feeder loading and generation to be able to configure the network for operational works. This helps operators to quickly identify potential issues and take corrective action before they cause major problems in the operation process.

The integrations required for the new SCADA AMDS system to operate are carried out through the ESB, which is the central guiding member in the distribution network modeling process managed by EL. ESB also provides CIM standards for data exchange (the data itself is stored in the CIM repository). The newly implemented SCADA ADMS system combines the network management system (DMS), OMS, and DERMS.

Figure 29 illustrates a basic SCADA system architecture:

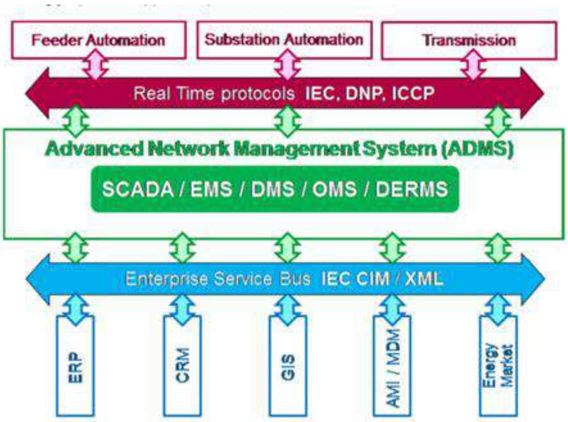


Figure 29. EL – SCADA System Architecture.

As evident from Figure 29, the ESB enables both static and dynamic data exchange with external systems based on IEC 61970 and IEC 61968 standards. Static data includes the network connectivity model and all network elements within the model, while dynamic data refers to measurements, device statuses, tags, temporary elements, DMS function results, etc. The solution allows complete CIM compatibility for external use and exposes data from internal ADMS data models according to the ADMS CIM profile with extensions. There is a need to present attributes and the methods in which distributed resources and self-supply (sending data to CIM repository, attribute recording, integration with ADMS, etc.) should be modelled and graphically represented in the system. It involves the conversion from one physical environment to another, digital one. Furthermore, the topic of how distributed resources, especially cases of self-supply with production behind the meter (commonly known as Net Metering), are included in the power flow calculation in the network needs to be addressed. The main characteristic of distributed resources, their weather-dependent power injections into the grid, must be highlighted and appropriately modeled. The result of digitization is the display of power flow calculations at different time instances depending on weather data.

SCADA systems use a variety of communication protocols to transmit data between the various components of the system. Some common protocols used in SCADA systems include Modbus, DNP3, and OPC-UA. These protocols allow for efficient and reliable data transmission, even over long distances. In addition to these standard protocols, many SCADA systems also incorporate advanced encryption and security features to ensure the integrity and confidentiality of the data being transmitted. This helps to protect against unauthorized access and other security threats that could compromise the operation of the production process. In EL, three protocols are used for data transfer from remote points, these being DNP3, IEC104 and ICCP.

Other Databases and Systems

Short Description of EMS or DMS and operations served.

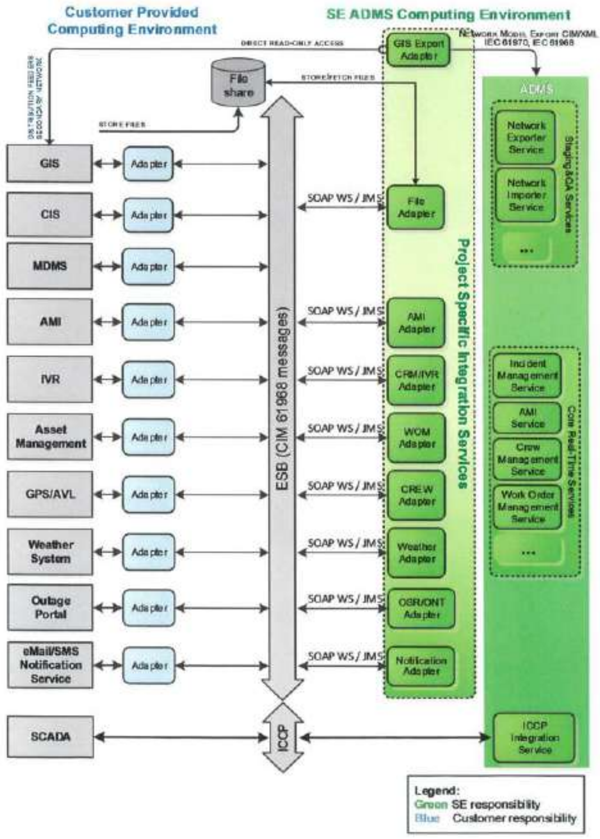


Figure 30. EL – ADMS System.

The SCADA management and control system of EL's distribution network is improved with the advanced ADMS system (Figure 30), which enables the execution of fundamental functions for the distribution network, such as determining the location and calculating the size of faults, performing reconfiguration and network load shedding, various calculations related to power losses and various findings of violations in the distribution network. One of the basic modules of ADMS are EMS and DMS. In the EL SCADA ADMS system, the assessment of the network state is performed almost in real-time based on the current topological model and current network configuration, status of switches, and load/production of users from the curves of the previous period. Since the assessment of the network state depends on many parameters, we want to constantly monitor the quality of these parameters. Therefore, we currently have a test application designed to validate the state estimator by comparing real-time data (graphically and statistically) with estimated data (Figure 31).

Figure 31. El – Outputs of the State Estimation Tool.

Brief information about Remote Terminal Units – RTUs

RTUs are integrated in our system and using appropriate communication protocols, which are integrated with FEP. ADMS real time in production zone integrates the DMD which pushes the data to the NDS whereby pulling the dynamics cache, the DMD real time is generated in ADMS as shown on Figure 32.

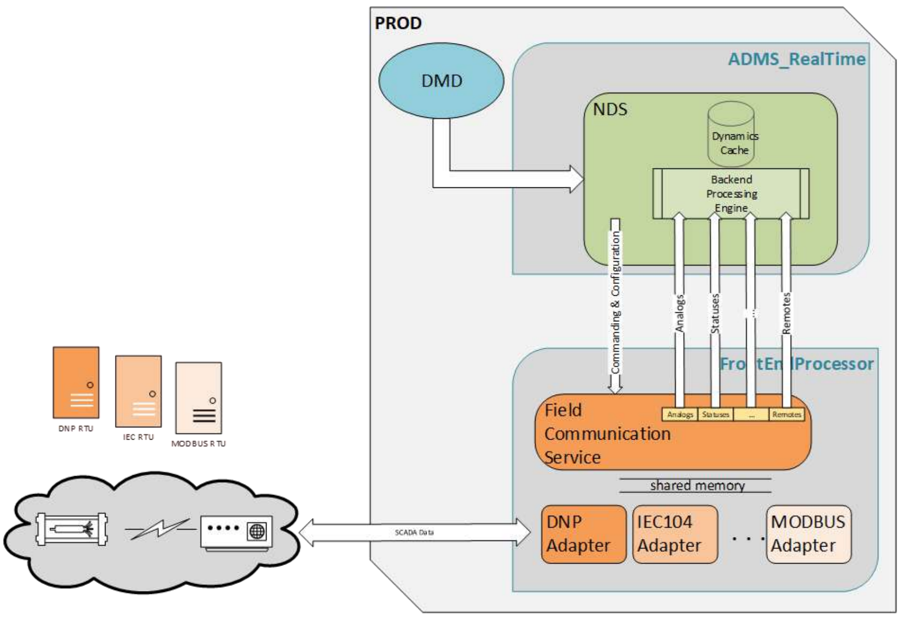


Figure 32. EL – Structure of the RTUs.

Short Description of failures databases and operations served.

The data flow for failures and redundant sites is shown on Figure 33.

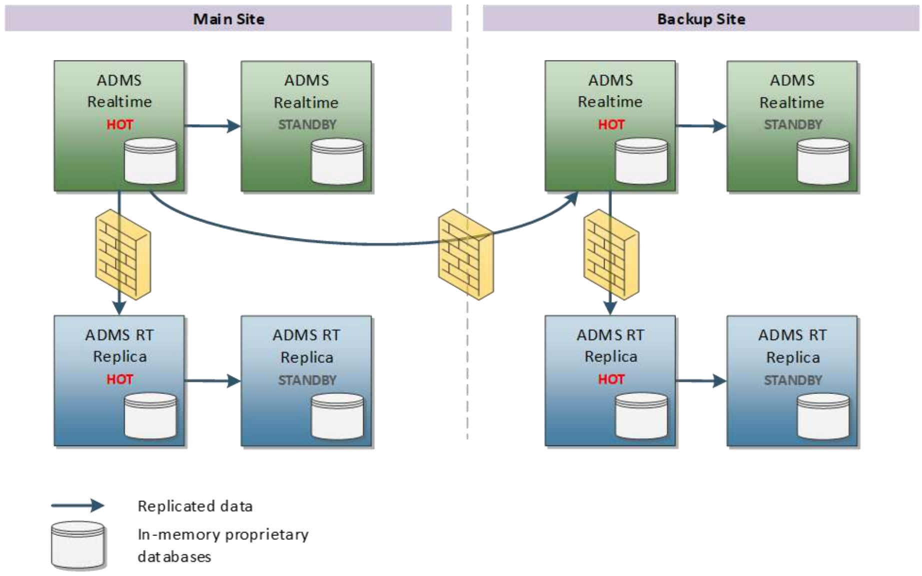


Figure 33. EL – Failures Data Flow.

EL uses three protocols for data transfer from remote points: DNP3, IEC104 and ICCP.

8.2.6 BARRIERS AND CHALLENGES

Table 17 highlights the potential obstacles and risks of the Slovenian pilot site, with a focus on Slovenian Demo's anticipated tasks on the OPENTUNITY project. Each criticality indicates the level of likelihood and impact, ranging from low to high, as well as a possible solution envisioned.

Table 17. Slovenian Demo - Criticalities log

Description of criticality	Likelihood	Impact	Ways to address criticalities
Meters not able to provide sufficient quality of measurements	LOW	HIGH	Reparameterization of the meters – if this will not work, new meters will need be installed.

8.3 SPANISH PILOT SITE

8.3.1 INTRODUCTION

The Spanish pilot is at the responsibility of Anell, with active participation from Estabanell Impulsa, Etra I+D, ICCS, HYP and NODES. Anell is a DSO situated in Catalunya, providing electrical services to 31 municipalities spanning from Granollers to Camprodon. Estabanell Impulsa is an energy retailer which operates in Catalunya and commercializes 100% renewable energy. Although Estabanell Impulsa and Anell are distinct legal entities, they both fall under the umbrella of the Estabanell company. The responsibility for developing the innovations to be tested in this pilot site lies within three partners, Etra I+D, ICCS, and HYP. At the same time, the role of NODES is to facilitate the implementation of a local flexibility market.

Over the course of this pilot, the perspectives of both the DSO and the energy retailer will be examined. In other words, certain use cases under investigation will provide benefits to the DSO by assisting grid management, whereas others are primarily of interest to the retailer, as they enable new flexibility services to be provided to its customers. It is worth noting that not all customers served by Anell have Estabanell Impulsa as their retailer of energy, and conversely, not all Estabanell Impulsa customers are connected to Anell's electricity network. Accordingly, in this document, when discussing the power grid, we will provide data from the DSO's perspective. When considering end-users, we will focus on the intersection of these two sets of customers.

Given the increased proliferation of DER and the existence of fraudulent actions, increased grid observability and assets management are of paramount importance in order to mitigate power losses and increase grid efficiency to the maximum level. There is also an interest in supporting the energy transition by fostering energy communities and promoting demand-side flexibility. These are the principal needs identified by Anell and Estabanell Impulsa, and they will be the focal points of the Spanish Pilot project.

8.3.2 LOCATION DETAILS

The locations of the pilot site are the municipalities of Santa Eulàlia de Ronçana and Balenyà. Santa Eulàlia de Ronçana, an urban and rural area of 14 km^2, was chosen due to the high frequency of non-technical loses alongside the substantial presence of photovoltaic solar panel installations, numbering approximately 120 with a collective maximum power capacity of around 1 MW. It should be mentioned that Santa Eulàlia de Ronçana is currently hosting a pilot project for an energy community, boasting participation from 30 residential members, a majority of whom have self-consumption photovoltaic panels. In the municipality of Balenyà, an energy community is currently in the process of development. Additionally, the construction of three Electric Vehicle (EV) charging points, that will be managed by Estabanell Impulsa over the next five years, has been initialized.

8.3.3 PILOT INFRASTRUCTURE

In Table 18, Table 19 and Table 20, information related to the Anell's power grid alongside the municipalities where the pilot will be located are included. With reference to the content of Table 21 Grid Information – peak demand, network losses and downtime, third-party causes encompass a variety of factors, including issues in adjacent distribution grids, transmission grid disruptions, acts of vandalism, and other external influences. While relatively common when considering the overall electrical grid, accounting for approximately 25% of all incidents, are not particularly concerning in the pilot area. To be noticed that there were no downtimes observed in 2022 due to auto-recloser failures, transformers, or human error in the areas of Santa Eulàlia de Ronçana or Balenyà. The most impacting causes on the pilot area, both in terms of frequency and duration of the downtime, are power line related issues and junction failures. In the pilot area, the most significant causes of disruptions, both in terms of their frequency and the duration of downtime, are related to power line issues and junction failures.

Additionally, Figure *34* and Figure *35* provide information for the Single-phase diagram from Santa Eulàlia de Ronçana and Single-phase diagram from Santa Eulàlia de Ronçana respectivelly.

Table 18. Anell – Grid Information – Network Length.

	Network length (km)		
Voltage	**Total Grid**	**Santa Eulàlia de Rončana**	**Balenyà**
Low Voltage (230 and 400 V)	1019	78.8	40.7
Medium Voltage (3-5 kV, 21kV, 40kV)	664	28.4	28.5

Table 19. Anell – Grid Information – Substations.

Type	Location	Transformer's rated power (MW)	Input Voltage (kV)	Output Voltage (V)	Number of substations
Secondary	Total	10 - 1000	~5 or ~21	230-420	774
	Balenyà	25 - 1000			32
	St Eulàlia de Rončana	50 - 1000			42
Primary MV/MV	Total	50 – 20 000	~21 or ~40	3-5 or ~21	24
	Balenyà	3 000 – 10 000	40	5 000 and 21 000	2
	St Eulàlia de Rončana	6 300 – 10 000	40	21 000	2
Primary HV/MV	Total	50 000 – 80 000	220	21 000 and 40 000	3

Table 20. Anell – Grid Information – Customers Served.

	Number of customers		
Type	Total Grid	Santa Eulàlia de Rončana	Balenyà
Residential	49872	1994	1719
Commercial/Businesses	8395	322	228
Industrial	868	143	72
Total	59 135	2459	2019

Table 21. Anell – Grid Information – Peak Demand, Network Losses, and Downtime.

		Latest Annual Network Downtime		
Latest Annual Peak Demand (kW)	**Latest Annual Network Losses (%)**	**Cause of downtime**	**System Average Interruption Duration Index (SAIDI)**	**System Average Interruption Frequency Index (SAIFI)**
Total: 95077 **St Eulàlia: 4189** **Balenyà: 5450**	12%	Power Line related issues Maximum Admissible Current Reached Overload Quality of Service Blown Fuse Sensor failure Junction failure Auto-recloser failure Transformer Human error Third party	Total: 0,31 St Eulàlia: 1,60 Balenyà: 0,25	Total: 0,92 St Eulàlia: 2,00 Balenyà: 1,02

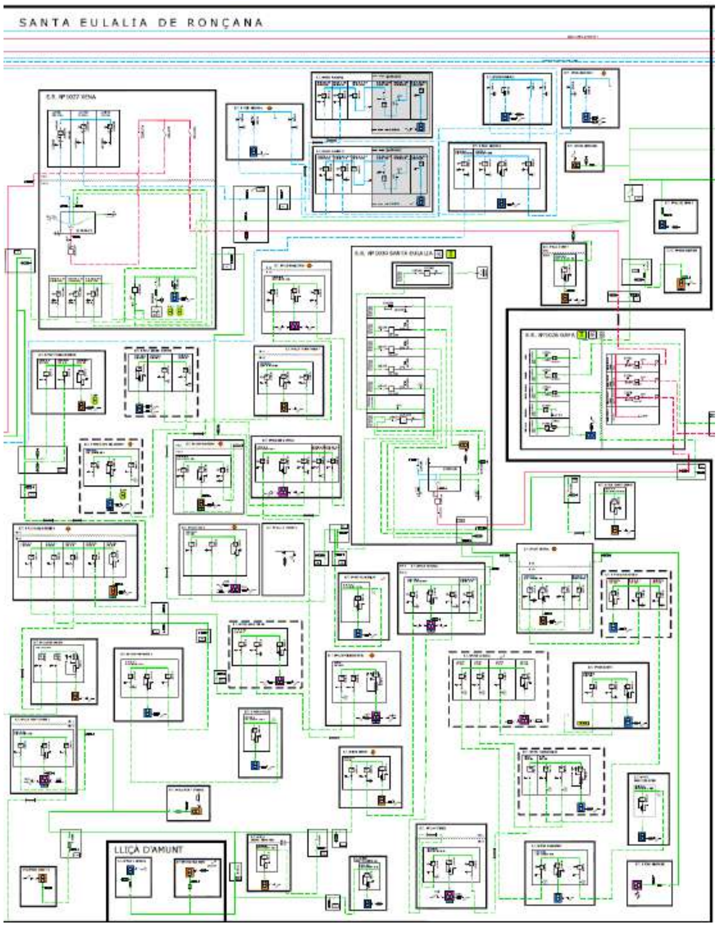


Figure 34. Anell – Single-phase Diagram from Santa Eulàlia de Ronçana.

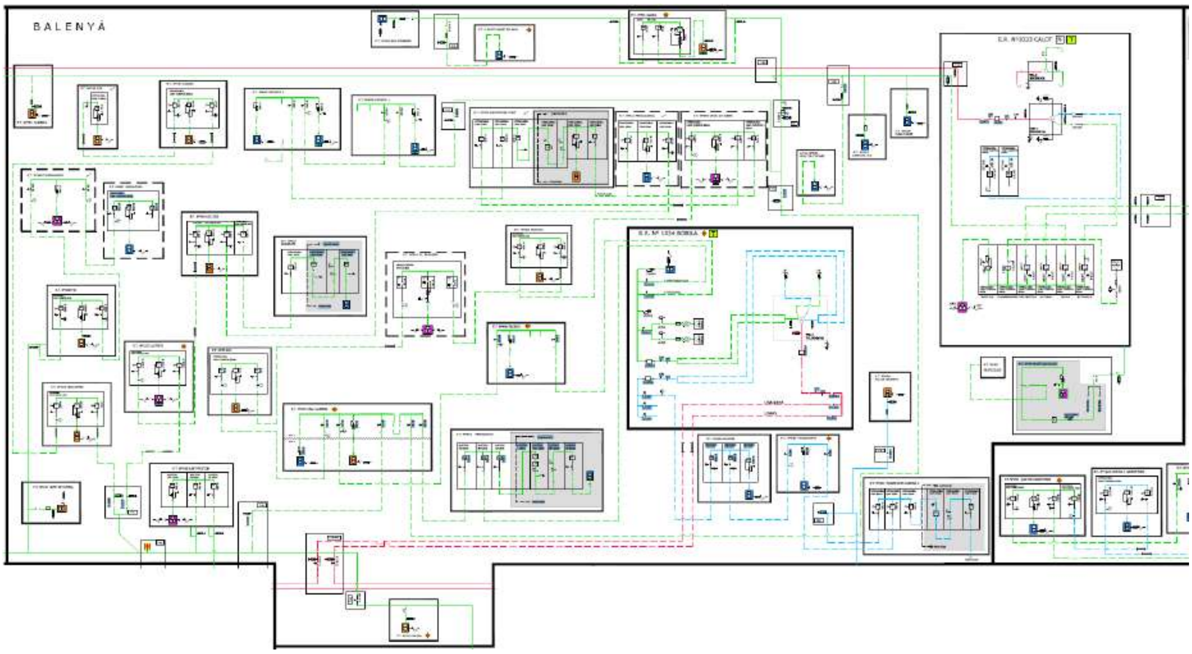


Figure 35. Anell – Single-phase Diagram from Balenyà.

8.3.4 PILOT TOOLS AND TECHNOLOGIES

8.3.4.1 SCADA

At Anell, SCADA is used to manage the medium voltage electrical grid and control energy flows. It allows both gathering real-time data and controlling equipment at remote locations. Thus, enabling data-driven based decisions regarding the grid operation. The SCADA system comprises both hardware and software components. The hardware components include transformer Taps, IED, RTU and FPI, gather and feed data into the Field Controller Systems, which is then forwarded and processed, until it reaches the Control Centre Room. RTUs are used both in primary and secondary substations for monitoring and controlling field devices and assets, such as switchgears, transformers Taps, auto-reclosers, amongst others. As they are an essential part of SCADA system they connected to its database. Most commonly used RTUs in the system are T-300 from Schneider Electric, PRX from Sitel and iRTU from iGRID.

The software used is TedisNet, operating on Windows with SQLServer databases. Some relevant features from TedisNet are the calculation of load distribution both in real time and in a simulation environment as well as the calculation of short circuit currents. The system also logs all events for reporting purposes and fires an alarm in case of fault, which can be sent via SMS, email, or radio. The DSO's quality indices are calculated based on the reported incidents with the CALSER application from TedisNet, following the Art. 103 of Spanish Constitution on quality of service.

Anell's DMS proactively suggests energy operational conditions to optimize the distribution grid. The primary objective is to deliver electricity in a manner that is more efficient, reliable, secure, and financially effective. It is embedded in the SCADA system, as a feature from TedisNet. The data, which includes electrical values, network connectivity and assets states, is collected from various devices, such as sensors, transducers, IEDs and RTUs. To ensure data integrity, raw data undergoes thorough checks. Afterwards, both raw and computed data are securely stored in a data centre, physically located at Anell's facilities. The data is processed through SCADA's application layer and stored for at least two years. At the end of each data collection cycle, the recorded readings undergo further processing through the SCADA system. The processed data is then archived in the same data centre. The architecture of the SCADA system is depicted in Figure *36* whereas the communication protocols that are followed are IEC 60870-5-104, Modbus TCP/IP, Prosa (currently not in use, legacy protocol from Sitel, TedisNet provider), PROCOME and SOAP (Web services).

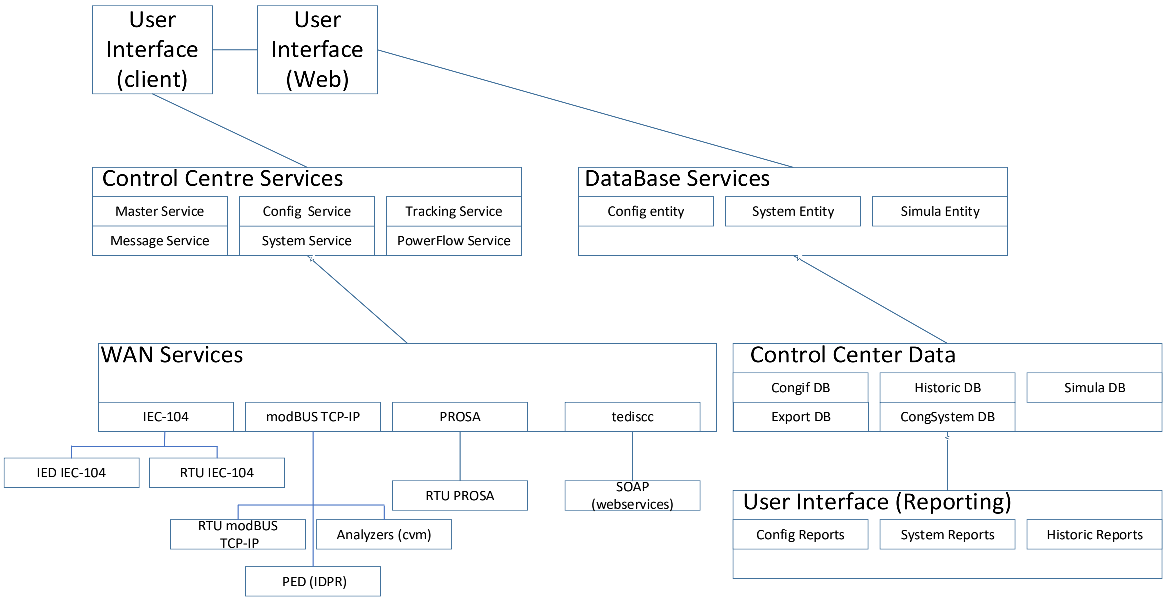


Figure 36. Anell – SCADA system architecture.

8.3.4.2 Short Description of GIS Systems and operations supported

Anell's grid geographical information, amongst other, is stored in a PostgreSQL database managed by an external provider, with which we interact mostly via QGIS open-source software. QGIS is used both for consultations and for updating the available information, as the visual support it offers is effective for relaying information across the company. QGIS has the advantage of offering added functionality with its multiple plugins, and the flexibility in accepting multiple vector file formats.

Our grid topology is available in terms of how the energy is distributed through the grid in a given moment. The topology has a static layer, which consists of the geographical information from the grid. There is also a dynamic layer, consisting of which lines are energised depending on which circuit breakers are open or closed, in other words, consisting of the arrangement of certain segments of the distribution circuits, which is managed and read via SCADA.

Adding to the communication protocols mentioned in the previous section, our systems also support the following standards: IEC-61850, Modbus RST485, STG-DC and OCPP.

In relation to the use cases involving end-users, the primary focus will be on those who are both clients of the DSO and retailer. The electricity consumption from 2022 regarding the aforementioned clients-consumers are depicted in the following table. It must be noted that in order to offer more detailed information about the end-users alongside their available equipment, their engagement in the project and further work is required.

8.3.5 DATA AND MEASUREMENTS

8.3.5.1 Homes/Buildings

During this pilot, for the use cases involving end-users we will focus on those who are both clients from the DSO and retailer. On the following table there is the electricity consumption in 2022 (Table 22) from the Anell's total consumers and from its consumers who are also Estabanell Impulsa's clients.

Table 22. Anell – Electrical consumption in 2022.

	Electricity consumption 2022 (GW)		
	Total Grid	Santa Eulàlia de Ronçana	Balenyà
Total Anell	522 234	25 065	21 755
Anell and Impulsa	276 164	14 864	9 375

8.3.5.2 Smart Metering

Anell's grid goes from Granollers, located near Barcelona, up north until Camprodon, with a total of 59.136 smart meters installed. As previously mentioned, the pilot for this project will take place in the municipalities of Santa Eulàlia de Ronçana, where there are 2.459 smart meters, and Balenyà, with 2.019 smart meters that are already installed. The AMI allows for remote data collection regarding costumers' energy consumption. It includes smart meters at the end user and DCU as well as the communication infrastructure and the information management system, BREO. The communication infrastructure consists mostly of PLC between smart meters and DCUs and BPLC between substations. In some areas, such as Santa Eulàlia de Ronçana, Optical Fibre and wireless LTE communications are also used. All communications follow the PRIME protocol. Measurements are made every 15 minutes from industrial clients with higher contracted power and on an hourly basis from the remaining consumers, then collected at the DCUs and sent once a day. Building/ Home energy management systems are not applicable for this pilot site.

8.3.6 BARRIERS AND CHALLENGES

An analysis of the potential risks for the pilot, their probability and impact, along with potential mitigative actions, has been made. The results are presented on Table 23.

Table 23. Anell – Criticalities log.

Description of criticality	Likelihood	Impact	Ways to address criticalities
Impossible to test some use cases in a real environment.	HIGH	LOW	Test them in a controlled environment in a laboratory.
Not enough years of historical data.	LOW	MEDIUM	Starting as soon as possible to collect and store the information needed.
Lack of an automated and easy way to share data from certain sources with the project partners.	LOW	MEDIUM	Work together with other departments in Anell to plan and setup such a pipeline.
Lack of data needed for some use cases	MEDIUM	MEDIUM	Collect all kinds of data available potentially useful for the use case and check with the respective technological partner if it is enough.
Lack of knowledge/experience for fulfilling some of the activities which are an aggregator's responsibility	MEDIUM	MEDIUM	Work together with the partners involved in the local flexibility market, to exchange knowledge and support

Final product is not user-friendly	MEDIUM	MEDIUM	Work closely with the developers of the product interface, provide them with feedback from the end-users (DSO staff or clients, depending on the use case).
Failing to activate flexibility when requested for technical reasons	HIGH	MEDIUM	Monitor equipment performance and connectivity
Failing to activate flexibility when requested, because even though the request is fulfilled a neighbor change their consumption patterns in a way that overall there is no change in the consumption in the area.	HIGH	MEDIUM	Monitor the whole area and see if more flexibility requests are needed to fulfil our goal
Failing to active flexibility because the requests don't match the users needs.	HIGH	MEDIUM	Understand the clients' limitations and priorities.
Failing to identify the activated flexibility.	HIGH	MEDIUM	Have regular communication with the end-users to know their perspective and share that information with the technological developers.
The budget is not enough for satisfying the pilot's needs	LOW	HIGH	Search for needed equipment and providers, plan for what's necessary in advance.
Miscommunication between partners	LOW	HIGH	Look for a close and frequent communication, and to make sure we are all in the same page
Lack of human resources for installing the necessary equipment	MEDIUM	HIGH	Work together with other departments in Anell to plan for needed installations.
Lack of clients interested in participating in the NILM or local flexibility market pilots	MEDIUM	HIGH	Reach to a big pool of people, explain why is flexibility important and highlight the advantages of participating in the pilot for them.
Lack of information to calculate certain KPIs and/or evaluate the effectiveness of some use cases.	HIGH	HIGH	Define how to do those calculations and look for the needed information and its potential sources in advance.

8.4 SWISS PILOT SITE

8.4.1 INTRODUCTION

Motta District is a suburban local Energy Community (EC) belonging to the district of Via Motta in the city of Massagno, located nearby Lugano in southern Switzerland (Figure 37). The community is owned by Azienda Elettrica di Massagno (AEM) SA which also operates as the Distribution System Operator (DSO) and the energy retailer in the municipality of Massagno, Capriasca and Isone.

8.4.2LOCATION DETAILS

Figure 37. AEM – Geographical Position of the Energy Community (Motta District)

The main objective of the Energy Community is to maximise the self-consumption for the community members by optimal managing the Renewable Energy Sources (RES) locally available.

Members are protected by Swiss law and may not be subject to a tariff with higher costs than the guaranteed common tariff fixed on an annual basis for all end users supplied by AEM. For this reason, all members of the community are charged the standard tariff. On the other hand, members of the energy community can benefit from an incentive mechanism for locally produced and self-consumed energy, which provides an additional bonus on an annual basis.

The community infrastructure consists of a variety of buildings such as residential buildings, offices, a warehouse, and an elderly care home. All the end-users belong to the AEM distribution network, and they are served by a 630 kVA MV/LV transformer, which is located in the neighborhood.

The residential area is made up of approximately 20 residential flats and a single house. The building stocks consists of a six-storey building, a three-storey building and 3 multifamily houses. The residential buildings host approximately 65 residents, covering a total floor area of approx. 11'000 m^2.

The total annual electrical consumption for residential houses is around 50 MWh. The district also includes a large office building (with an engineering and a legal office), a warehouse used daily, and an elderly care home with more than 50 single-bed rooms and approximately 90 workers. The office spaces have a total annual electrical consumption of 120 MWh, whereas the elderly care home is around 315 MWh.

Within the urban district, there is a solar photovoltaic system with a total installed capacity of 60 kWp (55 MWh of annual production), located on the roof of the elderly care home. A V2G-ready EV charging station (DC, 10 kW) is part of a car sharing service for the population and it is always connected to the same vehicle (Honda-e 35.5 kWh of electric storage). The car sharing service is also part of the community and can be used both as flexibility and as a battery storage solution.

In the energy community, the local energy production serves the needs of the elderly care home. Energy is first made available to the retirement home, followed by the rest of the community buildings, and finally the surplus is fed directly into the grid.

Regarding the energy mixture, AEM's energy mix is 50% renewable, with around 47% of the energy coming from hydropower. More details about our energy mix are available on our website at https://aemsa.ch/it/tariffe-e-regolamentio or to this websitehttps://www.strom.ch/it/service/etichettatura-elettricita.

The pilot site is leveraging the existing smart metering infrastructure, which is completely deployed and operational in the grid. Each Point of Delivery (POD) is equipped with a Smart meter capable to measure different value, like currents, voltages, and powers, apart from monitoring the net energy consumption. A suitable communication infrastructure is in charge of collecting data and send them to AEM's central servers. Data has a standard granularity of 15min with good quality historical data available since 2021.

A web-based monitoring tool for end users and the community manager tool are available online with the possibility of access via browser and mobile app. The end-users and the community manager have access to their personal data via web portal or mobile application.

The envisioned objective of the energy community thanks to the OPENTUNITY project, is primarily aiming at improved self-consumption and self-sufficiency levels, reduction of electricity injection to the main grid with the final goal of facilitating DERs penetration, and optimal end-user flexibility recruitment and compensation.

As part of the project, an active congestion management system will be developed and validated, with the aim of predicting and preventing possible congestion and overvoltages on the local distribution network, particularly by monitoring the load of the transformer located in the secondary substation. In addition, a local flexibility market will be introduced, where community-level assets can be aggregated for the purpose of offering services directly to the DSO or other companies operating in the sector.

8.4.3 PILOT INFRASTRUCTURE

The members of the energy community are supplied by the same MV/LV transformer station with 630 KVA of rated power and a ratio of 16 kV at the primary side and 0.4 kV at the secondary one (Figure 38).

The energy community is located 260m from the transformation cabin. The LV power lines downstream the cabinet are three phase underground. There are no overhead lines not only in the community, but in the entire municipality of Massagno.

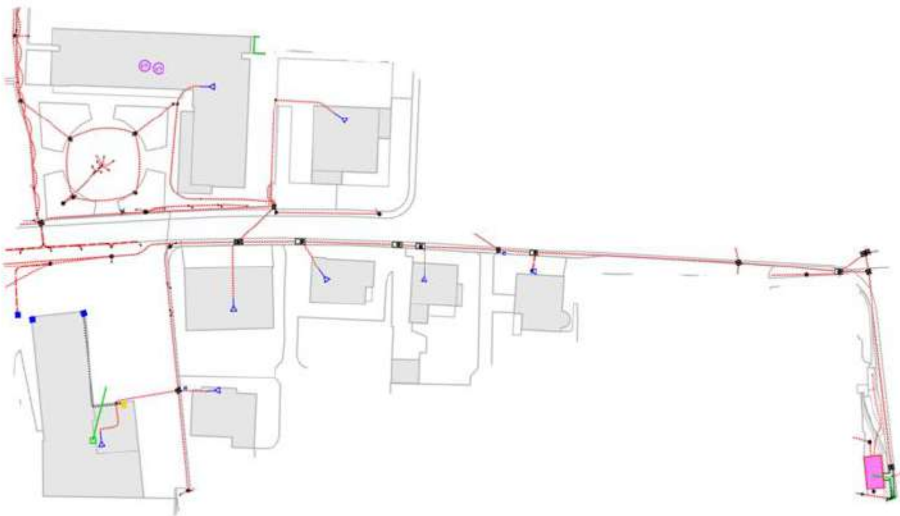


Figure 38. AEM – Motta District distribution grid.

Considering the size of the pilot, which consists of a single energy community fed by a portion of the distribution network, no periods of network downtime are encountered, and the continuity of the service is always guaranteed by the network configuration, which is meshed but operates radially (Table 24).

Table 24. AEM – Grid Information.

Latest Annual Peak Demand	Latest Annual Network Losses (%)
180 kW	2%

8.4.4 PILOT TOOLS AND TECHNOLOGIES

8.4.4.1 SCADA

The SCADA system only operates and manages the medium-voltage distribution network level. The energy community that is the subject of the pilot site is completely operated at low voltage and therefore the SCADA system is not relevant.

8.4.4.2 AMI infrastructure description

The LV distribution grid of the energy community is monitored and controlled by the fully deployed Advanced Metering Infrastructure (AMI). All the end-users are equipped with a smart meter at the point of connection with the grid. Each smart meter has the possibility to be connected to an interruptible or flexible load and control it according to the device possibilities.

The data collection is performed from the smart meters by the data concentrator, which are linked in turn to the Head-End System (HES); the device responsible for collecting, filtering, and managing the data. The HES communicates with different other tools, like the Meter Data Management (MDM), the

Data Management Platform (DMS), which is responsible for the data harmonization and the anonymised data provision to the external partners via API, the database, where the historical data are stored, and finally the flex manager, which is the tool responsible for sending the control signals to the flexible assets connected to the infrastructure.

The device used for measuring residential and small commercial utilities is the Landis+Gyr E450 (Figure 39), while for consumers and prosumers with higher energy consumption or local energy production the E570 model is commonly used.

Figure 39. Landis+Gyr E450.

In addition to the net energy consumption, which is measured every 15 minutes, as standard granularity, the energy meter is also able to monitor other fundamental electrical parameters, like voltages and currents per phase, active and reactive power, and the power factor. The granularity can be modified up to a sampling time of 1 minute.

8.4.4.3 The Geographical Information System (GIS)

A Geographical Information System (GIS) is used in AEM to store, manage, analyse, and present geospatial data for the entire distribution grid, both medium and low-voltage power lines.

It combines geographic information, such as maps and satellite imagery, with attribute data such as power lines or land use information (Figure 40). The GIS is primarily used to interact with and manipulate spatial data to gain insights, make informed decisions, and perform analyses to manage and develop the network itself.

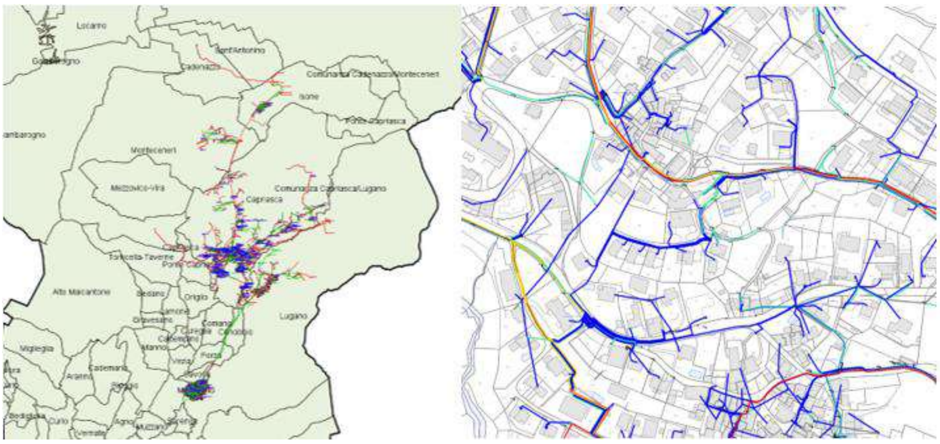


Figure 40. Overview of the AEM's distribution grid (Left) and detail of Massagno area (right).

In Table 25 are listed the datasets that will be available from the GIS that may be useful for the project applications.

Table 25. AEM – Grid equipment list.

Element	Geographical coordinates*	Additional information
Trafo cabin	Yes	- Trafo technical specs - LV side connections
Distribution cabinet	Yes	- LV side connections
Point of Delivery (POD)	Yes	- PV power (if any) - PV date of installation (if any)
Cables & lines	Yes	- Length - Cross section - Material - Technical specs

* According to AEM's privacy policy only anonymized data will be shared with project partners.

8.4.5 DATA AND MEASUREMENTS

Data collected, stored, and processed

AEM recently started the implementation in its distribution network of a data management platform called Flexo. Flexo is developed by Hive Power, and it is designed to provide end users and community managers with real-time insights into energy consumption and generation. The Flexo tool monitors a range of parameters related to energy consumption and generation. This data is gathered from a variety of sources, including smart meters, sensors, and other IoT devices, as well as from external data feeds such as weather reports and energy market data.

In addition to its monitoring capabilities, Flexo also offers a range of services to help users optimize their energy consumption and generation. These services include real-time alerts and notifications, automated energy management tools, and detailed reporting and analysis tools to help users better understand their energy usage patterns.

For third party users, Flexo offers an optional read-only access. This view provides read-only access to sites and devices metadata and measurement data, allowing partners to monitor energy usage in real-time at specific locations.

Flexo also offers an API and RabbitMQ integration, providing access to anonymized data from the platform. This allows partners to develop custom applications and integrations using the Flexo data, enabling them to offer a wider range of energy management services to their own customers. A concept of Flexo diagram is shown on Figure 41.

Figure 41. Flexo Concept Diagram.

Data from the smart meters will be accessible to selected project partners through the Flexo platform using RabbitMQ or RestAPI.

In Motta District energy community smart meters are installed for every Point of Delivery (every electricity consumer, including EV charging stations). Smart meters are also used to measure the generation of local PV systems, which is mandatory for installed capacity greater than 30 kWp (e.g., Building cluster #1).

8.4.5.1 Homes/Buildings

The demo site enables a charging station whose characteristics are depicted in Table 26, and a set of buildings in Motta District energy community (Figure 42). The type of buildings is presented below:

- Elderly care home (5-storey) with 62 residents and 90 workers (Table 27),
- Warehouse (2-storey) with 5 workers (Table 28),
- Office building (5-storey) with 51 workers (Table 29),
- Residential_1 (6-storey) with 35 residents (Table 30),
- Residential_2 (3-storey) with 10 residents (Table 31),
- Residential_3 (2-storey) with 8 residents (Table 32),
- Residential_4 (2-storey) with 8 residents (Table 33) and,
- Residential_5 (2-storey) with 4 residents (Table 34).

Figure 42. AEM – Area of interest of the energy community.

Table 26. AEM – Demo Site – Car sharing service.

Demo-Site – Car sharing service	
(1) Bidirectional EV charging station	
Manufacturer, Model	EVTEC, sospeso&charge
Charging point	1
Tech Specs	Rated power: DC 10kW Connector: CCS Technology: Vehicle-2-Grid (V2G)
(2) Vehicle	
Manufacturer, Model	Honda-e
Tech Specs	Storage capacity: 35.5 kWh

In addition to the charger of Table 26, two additional EV changing stations are planned to be installed close to the warehouse. The EV charger model identified is ENELION LUMINA, a monodirectional charging station with a charging power up to 11kW 3-phase and interoperability protocols including OCPP. The expected timeframe of the new infrastructure installation is Q4-2023.

Table 27. AEM – Demo – Site Building Cluster #1.

Demo-Site Building Cluster #1 [Elderly care home]		
Basic info		
1	**Location**	Massagno
2	**Year of construction**	Between 1996-2005
3	**Recent renovation**	Yes, year not specified
4	**Gross floor area (m2)**	4500 (estimate)
5	**Number of stories**	5
6	**Number of zones/ apartments**	62 individual rooms
7	**Operating periods**	24/7 for 365 days per year
8	**Energy service contract**	Electricity: - Flat energy tariff (the user pays a fixed value for the entire year [CHF/kWh]) - Peak power tariff (the user pays for the monthly peak power [CHF/kW])
9	**Flexibility service contract**	No
Energy info		
10	**Carriers**	Electricity Oil boiler
11	**Annual consumption per carrier (MWh/y)**	Electricity: 315 MWh/y Space heating and domestic hot water: 65'000 L/y → 540 MWh/y as a result of a total 635 MWh/y – oil fuelled boiler (85% efficiency) Cooling: air conditioning system (included in the electricity)
12	**Annual cost per carrier (€/year)**	Electricity: 60'000 – 85'000 CHF/year (private personal data of the consumer) Heating: 35'000 – 45'000 CHF/year (rough estimation)
Electrical Cooling system		
23	**Manufacturer**	(1) HIdROS (2) Mitsubishi El. (3) Mitsubishi El. (4) Carrier
24	**Nominal power**	(1) 50.40kWth, 18.60 kWel

		(2) 22.4kWth, 9.00 kWel (3) 22.4kWth, 9.00 kWel (4) 6.50kWth, 3.4 kWel
25	**Annual energy consumption**	25% of total electricity consumption (all)
27	**Smart controls**	No No No No
29	**Data collection**	No
	Renewable energy on-site	
30	**Type**	Solar Photovoltaic system
31	**Power output electricity**	60 kWp
34	**Connectivity**	Smart Meter
35	**Data collection**	Yes
	Energy storage	
36	**Type**	Hot water tanks
38	**Smart controls**	No
39	**Connectivity**	No
40	**Data collection**	No
	Lighting	
41	**Type**	180 x incandescent + 45 x led + 20 x fluorescent tubes (soon to be all LED)
42	**Dimming capability**	No
43	**Smart controls**	No
44	**Connectivity**	No
45	**Data collection**	No

Table 28. AEM – Demo – Site Building Cluster #2.

	Demo-Site Building Cluster #2 [warehouse]	
	Basic info	
1	**Location**	Massagno

2	**Year of construction**	Between 1919 and 1945
3	**Recent renovation**	None in the last 20-30 years
4	**Gross floor area (m2)**	2000 (estimate)
5	**Number of stories**	2
6	**Number of zones/ apartments**	10 zones (estimate)
7	**Operating periods**	5 days per week for the entire year
8	**Energy service contract**	Electricity: - Flat energy tariff (the user pays a fixed value for the entire year [CHF/kWh]) - Peak power tariff (the user pays for the monthly peak power [CHF/kW])
9	**Flexibility service contract**	No
	Energy info	
10	**Carriers**	Electricity
11	**Annual consumption per carrier (MWh/y)**	Electricity: 50 MWh/y
	Electric Heating system	
13	**Manufacturer**	Various
14	**Type of heat generator**	Space heating: (1) 2x Portable electric heaters (2) 1x Portable electric radiator (3) 2x Wall electric heaters with fan (4) 2x Wall electric heaters DHW: (5) 1x Electric resistance boiler
16	**Nominal power**	(1) 2kW, 9kW (2) 2kW (3) 5kW, 2kW (4) 2kW, 2kW (5) 1kW
17	**Annual energy consumption**	Space heating: 40% of the total building consumption (estimate) DHW: 10% of the total building consumption (estimate)
19	**COP**	1
20	**Smart controls**	(1) Yes with a smart plug after some modifications

		(2) No (3) No, Yes with a smart plug after some modifications (4) Both Yes with a smart plug after some modifications (5) Yes with a smart plug after some modifications
22	**Data collection**	No
	Lighting	
41	**Type**	100 x incandescent + 25 x fluorescent tubes
42	**Dimming capability**	No
43	**Smart controls**	No
44	**Connectivity**	No
45	**Data collection**	No

Table 29. AEM – Demo – Site Building Cluster #3.

	Demo-Site Building Cluster #3 [office]	
	Basic info	
1	**Location**	Massagno
2	**Year of construction**	Between 1991 and 1995
4	**Gross floor area (m2)**	1250 (estimate)
5	**Number of stories**	5
6	**Number of zones/ apartments**	6 apartments + 2 offices
7	**Operating periods**	5 days per week for the entire year (offices) 7/7 days per week for the entire year (apartments)
8	**Energy service contract**	Electricity: - Flat energy tariff (the user pays a fixed value for the entire year [CHF/kWh]) - Peak power tariff (the user pays for the monthly peak power [CHF/kW])
9	**Flexibility service contract**	No
	Energy info	
10	**Carriers**	Electricity Gas
11	**Annual consumption per carrier (MWh/y)**	Electricity: 120 MWh/y

		Space heating and domestic hot water: 84 MWh/y (gas boiler) Cooling: air-conditioning system (included in electricity)
Electrical Cooling system		
23	**Manufacturer**	NEMO A - T20 P1 J3 (Water chillers)
24	**Nominal power**	2 x 20 kWth, 2 x 5 kWel
25	**Annual energy consumption**	15% of the total electricity
26	**Efficiency rate**	4
29	**Data collection**	No
Energy storage		
36	**Type**	Hot water tank
38	**Smart controls**	No
40	**Data collection**	No
Lighting		
41	**Type**	100 x incandescent + 50 x fluorescent tubes
42	**Dimming capability**	No
43	**Smart controls**	No
44	**Connectivity**	No
45	**Data collection**	No

Table 30. AEM – Demo – Site Building Cluster #4.

Demo-Site Building Cluster #4 [residential building #1]		
Basic info		
1	**Location**	Massagno
2	**Year of construction**	Between 1919 and 1945
3	**Recent renovation**	-
4	**Gross floor area (m2)**	500 (estimate)
5	**Number of stories**	3
6	**Number of zones/ apartments**	4
7	**Operating periods**	Mostly outside of office hours (08:00 – 18:00) and weekends

8	**Energy service contract**	Electricity: - Flat energy tariff (the user pays a fixed value for the entire year [CHF/kWh]) - Peak power tariff (the user pays for the monthly peak power [CHF/kW])
9	**Flexibility service contract**	No
	Energy info	
10	**Carriers**	Electricity Oil
11	**Annual consumption per carrier (MWh/y)**	Electricity: 10 MWh/y Space heating and domestic hot water: 82 MWh/y (oil boiler) Cooling: not applicable
	Energy storage	
36	**Type**	Hot water tank
	Lighting	
41	**Type**	30 x incandescent
42	**Dimming capability**	No
43	**Smart controls**	No
44	**Connectivity**	No
45	**Data collection**	No

Table 31. AEM – Demo – Site Building Cluster #5.

	Demo-Site Building Cluster #5 [residential building #2]	
	Basic info	
1	**Location**	Massagno
2	**Year of construction**	Between 1946 and 1960
3	**Recent renovation**	-
4	**Gross floor area (m2)**	1500 (estimate)
5	**Number of stories**	6
6	**Number of zones/ apartments**	14
7	**Operating periods**	Mostly outside of office hours (08:00 – 18:00) and weekends

8	**Energy service contract**	Electricity: - Flat energy tariff (the user pays a fixed value for the entire year [CHF/kWh]) - Peak power tariff (the user pays for the monthly peak power [CHF/kW])
9	**Flexibility service contract**	No
	Energy info	
10	**Carriers**	Electricity Oil
11	**Annual consumption per carrier (MWh/y)**	Electricity: 15 MWh/y Space heating and domestic hot water: 171 MWh/y (estimate - oil boiler) Cooling: not applicable
	Energy storage	
36	**Type**	Hot water tank
40	**Data collection**	No
	Lighting	
41	**Type**	100 x incandescent
42	**Dimming capability**	No
43	**Smart controls**	No
44	**Connectivity**	No
45	**Data collection**	No

Table 32. AEM – Demo – Site Building Cluster #6.

	Demo-Site Building Cluster #6 [residential building #3]	
	Basic info	
1	**Location**	Massagno
2	**Year of construction**	Between 1946 and 1960
3	**Recent renovation**	-
4	**Gross floor area (m2)**	400 (estimate)
5	**Number of stories**	3
6	**Number of zones/ apartments**	3

7	**Operating periods**	Mostly outside of office hours (08:00 – 18:00) and weekends
8	**Energy service contract**	Electricity: - Flat energy tariff (the user pays a fixed value for the entire year [CHF/kWh]) - Peak power tariff (the user pays for the monthly peak power [CHF/kW])
9	**Flexibility service contract**	No
	Energy info	
10	**Carriers**	Electricity Oil
11	**Annual consumption per carrier (MWh/y)**	Electricity: 5 MWh/y Space heating and domestic hot water: 69 MWh/y (estimate - oil boiler) Cooling: not applicable
	Energy storage	
36	**Type**	Hot water tank
40	**Data collection**	No
	Lighting	
41	**Type**	30 x incandescent
42	**Dimming capability**	No
43	**Smart controls**	No
44	**Connectivity**	No
45	**Data collection**	No

Table 33. AEM – Demo – Site Building Cluster #7.

	Demo-Site Building Cluster #7 [residential building #4]	
	Basic info	
1	**Location**	Massagno
2	**Year of construction**	Between 1919 and 1945
3	**Recent renovation**	-
4	**Gross floor area (m2)**	400 (estimate)
5	**Number of stories**	3

6	**Number of zones/ apartments**	3
7	**Operating periods**	Mostly outside of office hours (08:00 – 18:00) and weekends
8	**Energy service contract**	Electricity: - Flat energy tariff (the user pays a fixed value for the entire year [CHF/kWh]) - Peak power tariff (the user pays for the monthly peak power [CHF/kW])
9	**Flexibility service contract**	No
	Energy info	
10	**Carriers**	Electricity Oil
11	**Annual consumption per carrier (MWh/y)**	Electricity: 10 MWh/y Space heating: 59 MWh/y (oil boiler) Domestic hot water: boiler with resistance (included in electricity – 10% of the total) Cooling: not applicable
	Electric Heating system	
14	**Type of heat generator**	3x Electric resistance boiler for DHW
16	**Nominal power**	3x 1.5 kW (1 per apartment)
22	**Data collection**	No
	Energy storage	
36	**Type**	Hot water tank
40	**Data collection**	No
	Lighting	
41	**Type**	30 x incandescent
42	**Dimming capability**	No
43	**Smart controls**	No
44	**Connectivity**	No
45	**Data collection**	No

Table 34. AEM – Demo – Site Building Cluster #8.

Demo-Site Building Cluster #8 [residential building #5]

	Basic info	
1	**Location**	Massagno
2	**Year of construction**	Between 1919 and 1945
3	**Recent renovation**	-
4	**Gross floor area (m2)**	300 (estimate)
5	**Number of stories**	2
6	**Number of zones/ apartments**	1
7	**Operating periods**	Mostly outside of office hours (08:00 – 18:00) and weekends
8	**Energy service contract**	Electricity: - Flat energy tariff (the user pays a fixed value for the entire year [CHF/kWh]) - Peak power tariff (the user pays for the monthly peak power [CHF/kW])
9	**Flexibility service contract**	No
	Energy info	
10	**Carriers**	Electricity Oil
11	**Annual consumption per carrier (MWh/y)**	Electricity: 10 MWh/y Space heating and domestic hot water: 60 MWh/y (oil boiler) Cooling: not applicable
	Energy storage	
36	**Type**	Hot water tank
40	**Data collection**	No
	Lighting	
41	**Type**	25 x incandescent
42	**Dimming capability**	No
43	**Smart controls**	No
44	**Connectivity**	No
45	**Data collection**	No

8.4.5.2 Smart Metering

As illustrated in Figure 43, data is sent from the on-field device up to the HES until reaching the AEM's database, leveraging a dedicated communication infrastructure.

Each Smart Meter communicates via PLC with the Data Concentrators installed at the LV distribution cabinets. The concentrators in turn send and receive information to/from the gateways installed at the MV/LV substations by means of 5 GHz Radio Frequency Broad Band technology. Finally, data is sent from substations to the servers leveraging the Optical Fibre rings infrastructure.

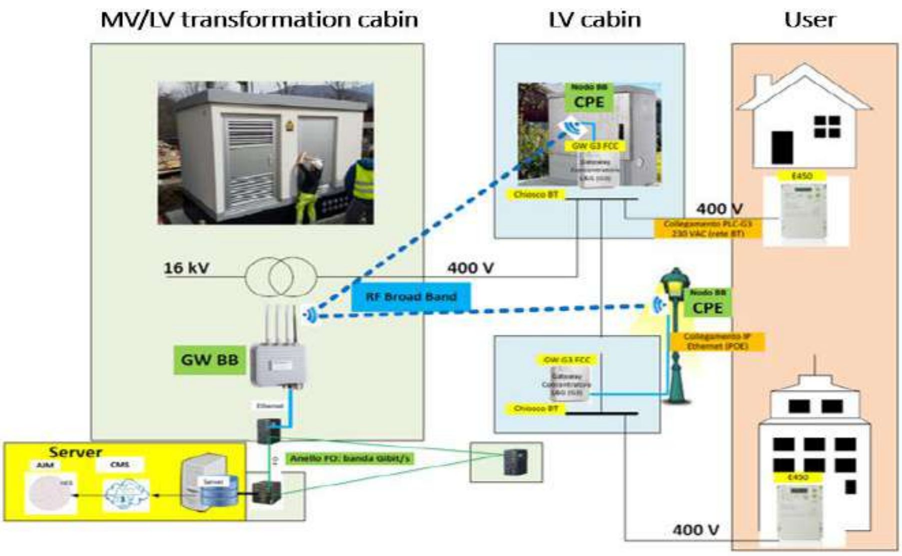


Figure 43. Smart Meter Communication Infrastructure Scheme.

8.4.6 BARRIERS AND CHALLENGES

Table 35 describes the possible challenges and criticalities of the Swiss pilot site, with a focus on planned installations and data availability. Each criticality shows the level of likelihood and impact from Low to High and a possible way of dealing with it envisaged by the owner of the pilot site.

Table 35. AEM – Criticalities Log.

Description of criticality	Likelihood	Impact	Ways to address criticalities
Delay in delivery of equipment to be installed	LOW	MEDIUM	Order devices well in advance and rely on reliable and experienced suppliers.
Lack of end-user participation	MEDIUM	MEDIUM	AEM maintains a close relationship of trust with its customers. Regular awareness-raising activities are organized to inform and increase user participation in energy community projects.
Technical installation problems with grid metering devices	LOW	MEDIUM	A preliminary assessment of the possible installation of metering equipment in the substation and in the MV/LV distribution cabinet has already been carried out. The equipment to be installed

			meets all the necessary requirements for installation and commissioning at the specified locations.
Difficulties in data collection	LOW	MEDIUM	Data collection from the devices to be installed is already up and running for all Landis+Gyr smart meters and has already been extensively tested for the other devices under evaluation.

9 CONCLUSIONS

The first step for producing technological solutions of high value for the end-users of OPENTUNITY (mainly DSOs, TSOs, prosumers and aggregators) is the proper definition of the requirements (functional, operational, legal, etc.) to which each OPENTUNITY innovation must adapt. To this end, the Volere methodology has been employed and a corroborative and iterative process has been followed. Four rounds of requirements definition, validation and revision have been successfully completed, with all partners contributing to the process using their own technical expertise. As a result, **82 requirements have been identified** in total, each one intended to describe specific characteristics of the OPENTUNITY technologies. Apart from the description and type of the requirement, specific acceptance criteria have been described, while, keeping a realistic view of the matter, a priority is assigned to each requirement referring to the development process of each Innovation.

Moving on to the demonstration activities, the various situations where the OPENTUNITY technologies will prove to be significantly advantageous for OPENTUNITY end-users are defined. The **21 Use Cases** are categorized under five HL-UCs each one directed towards a different Pilot Site of the project and one being horizontal (directed towards more than one Pilot):

- HL-UC 1: Horizontal
- HL-UC 2: Greece
- HL-UC 3: Slovenia
- HL-UC 4: Spain
- HL-UC 5: Switzerland

The UCs defined within each HL-UC will be used as a basis for the demonstration activities to be performed.

These demonstration activities will be performed in the four Pilot Sites also described in this deliverable. **Although they need some updates, the Pilot Sites will be completely capable of deploying the agreed Use Cases**. In every Pilot Site, at least one DSO is involved in the project and also a bunch of domestic users and assets capable of providing flexibility.

It is also noteworthy that impact assessment and up-scaling of the findings of the Project require tangible evidence. **49 KPIs have been defined**. Each one of the KPIs is intended to quantify the results of the application of the proposed solutions and UCs (possibly more than one). **According to the KPIs and Pilot Site analysis sections, it can be concluded that a cross-validation of the results will be possible after demonstration activities.**

10 References and acronyms

10.1 References

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10.2 Acronyms

Table 36. Acronyms

Acronym	Explanation
ADMS	Advanced Distribution Management System
AMI	Advanced Metering Infrastructure
AMR	Automatic Meter Reading
BEMS	Building Energy Management System
BPLC	Broadband PLC
CCS	Central Control System
CHP	Combined Heat and Power

CIM	Common Information Model
DCU	Data Concentrator Units
DER	Distributed Energy Resources
DERMS	Distributed Energy Resources Management
DMC	Distribution Management Centre
DMS	Distribution Management System
DR	Demand Response
DS	Distribution Station
DTS	Distribution Transformer Substation
ESB	Enterprise Service Bus
EV	Electric Vehicle
EVCS	Electric Vehicle Charging Station
FEP	Front End Processor
FLISR	Fault Location Isolation and Supply Restoration
FPI	Fault Passage Indicator
HEMS	House Energy Management System
HES	Head End System
HL-UC	Hich-Level Use Case
ICT	Information and Communication Technology
IED	Intelligent Electronic Devices
KPI	Key Performance Indicator
LTE	Long Term Evolution
MDM	Meter Data Management
OCPP	Open Charge Point Protocol
OMS	Outage Management System
PCU	Process Communication Units
PLC	Power Line Communication
RCS	Remote Communication Server
RES	Renewable Energy Sources

RTU	Remote Terminal Unit
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SAS	Substation Automation Systems
SCADA	Supervisory Control And Data Acquisition
SE	State Estimator
TS	Transformer Station
TSO	Transmission System Operator
UC	Use Case

11 ANNEXES

11.1 ANNEX I: ACTOR LIST

In order to establish a common understanding and language regarding the actors involved in the Use Cases defined within OPENTUNITY, a list of actors is defined. Each one can belong to one of three types (device, application, organization) and can be implicated in the UC directly or indirectly. It has been based using the Harmonised Electricity Role Model of ENTSO-E [10].

Table 37. OPENTUNITY Actor list

Actor	Description
Aggregator	Entity or grouping of agents (i.e., consumers, producers or any mix of them) that aggregate flexibility of disperse DERs with the aim of providing services to the Supplier, the DSO or the TSO via bilateral agreements or by trading in the flexibility market.
Consumer	A party that consumes energy. There is no distinction between residential end-users, small and medium-sized enterprises or industrial users. *Additional information:* This is a Type of Party Connected to the Grid.
DSO	*Distribution System Operator*. The entity responsible for: operating, planning, and developing the distribution network; guarantee the safe and secure operation and management of the distribution system; for data management associated with the use of the distribution system; for procurement of flexibility services.
Energy Management System	A system that monitors, controls and optimizes the operation of the energy system under supervision. No distinction between an Energy Management System for a Distribution Grid, a Building, an EV fleet…
ESCO	An *Energy Service COmpany* is a company that offers energy services which may include implementing energy-efficiency projects (and also renewable energy projects). They provide their energy services to final energy users, including the supply and installations of energy efficient equipment, and/or the building refurbishment.
EV Fleet Manager	*Electric Vehicle Fleet Manager*. An organization that operates and controls an EV fleet.
EVSE Operator	*Electric Vehicle Supply Equipment Operator*. The entity responsible for managing and operating the EV charging infrastructure.
FSP	*Flexibility Service Provider*: A party that offers flexibility services such adaption of consumption and/or production. An FSP can be an independent entity or an Aggregator
Flexibility Market Operator	A party that operates a market platform and manages the associated services to ensure the correct market clearing of registered bids and offers as well as the validation and settlement of each transaction.
Market Operator	A party that ensures the correct clearing of electricity sell and buy orders as well as their associated validation and settlement.

	In a more detailed description, the Market Operator provides a service of collecting offers to sell and bids to buy electricity and matching these offers and bids in order to determine a market price at the clearing point. This activity can be conducted in the forward, days-ahead and/or intraday timeframes, and can be combined with transmission capacity allocation in the context of market coupling. This is usually an energy/power exchange or platform.
OEM	An *Original Equipment Manufacturer* is a company that manufactures and sells products. *Additional information:* In the context of OPENTUNITY, those products may be HVACs, Lighting, Batteries etc.
Producer	A party that generates electricity.
Prosumer	An entity that consumes and produces energy. There is no distinction between residential end-users, small and medium-sized enterprises or industrial users.
Retailer	A Retailer supplies electricity to or takes electricity from a party connected to the grid at an Accounting Point. *Additional information:* An Accounting Point can only have one retailer. It can also take the role of Energy Community responsible.
TSO	*Transmission System Operator*. A party that is responsible for the stable power system operation (including the organization of physical balance) of the transmission grid in a geographical area. Its mission is to ensure the country's electricity's transmission in an adequate, secure, efficient, and reliable manner. Additionally, TSO is responsible for the operation of the balancing market.

11.2 ANNEX II: LIST OF USE CASES

11.2.1 HORIZONTAL

UC 1.1	**Short-term analysis of the impact of DER in the Distribution grid**
Description	The penetration of DER (mainly PV on roof) installed by energy communities may cause impact (congestions) in the Distribution Grid due to bidirectional electricity flows. This Use Case will tackle this issue and will provide a technology path to: - Forecast the power flows (taking into account demand and generation) of the grid (24 hours in advance). - Predict when the distributed PV will feed the grid (24 hours in advance). - Calculate which is the impact in the grid of this bidirectional flow (mainly to study the voltage variations in the affected line in the transient state). With the analysis performed, the DSO will be able to define the best strategy to solve the congestion according to their resources and capabilities.
Actors involved	- DSO. - Prosumers. - EMS (Grid Energy Management System - ETER). - Weather forecast provider. - AMI (Advanced metering infrastructure).
Triggering Event	There are prosumers feeding electricity into the grid, so the DSO needs to have a refined management of the grid.
Pre-condition	- Information about size and distribution of DER within the grid. - Surplus/energy injection/export curves. - Topology of the grid (this can be extracted from another UC). - SCADA measurements. - Access to GIS. - Temperature forecasts.
OPENTUNITY innovations involved	Topology identification and state estimation via machine learning.
Post-condition	EMS calculates (and shows to the DSO) which is the impact in the grid of this bidirectional flow (mainly to analyse the voltage variations in the affected line in the transient state).

Basic Path

Step No.	**Event**	**Description of process/ Activity**	**Info. exchanged**	**Actor producing the information**	**Actor receiving the information**
1	Periodic	SCADA data gathering	Grid measurements	DSO (SCADA)	EMS
2	Periodic	Prosumer data gathering	DER measurements	Prosumer (Smart meter)	EMS
3	Periodic	Weather forecast gathering	Weather forecast	Weather forecast provider	EMS
4	Periodic	Transient security analysis	Security analysis results	EMS	DSO

Realization	
Main responsible partners (Author)	- ETRA
Contributing partners	- ANELL - IMPULSA - AEM - SUPSI - HIVE
Priority	High

UC 1.2	**Application of NILM for consumers energy awareness**
Description	Capturing the data from smart meters, the NILM will analyze the consumption of the linked meter and will disaggregate the consumption into the main consumption devices. The focus will be put on the main appliances like HVAC, lighting, refrigerator, TV, washing machine, dishwasher, dryer and electric boiler. The NILM algorithms may be embedded into IoT smart devices (mainly smart meters) or deployed in the cloud in order to run. The goal is to identify and analyze the energy consumption patterns of customers to facilitate the reduction of their energy consumption and detect anomalies that may mean an incorrect functioning of an asset. Linked to this, this NILM functionalities will also be the basis for estimating the actual Energy Efficiency Label of the asset based on EU regulation 2021/340 of 17 December 2020.
Actors involved	- Consumer - EMS (Building Energy Management System or Home Energy Management System) - ESCO - AMI (Advanced metering infrastructure). - Smart home gateway. - NILM Module
Triggering Event	An ESCO needs to understand the energy behaviour of a consumer without submetering.
Pre-condition	To receive the energy consumption data from the smart meters periodically.
OPENTUNITY innovations involved	AI non-intrusive load monitoring algorithms as a low-cost technology for sensorless prosumers.
Post-condition	EMS shows (to both ESCO and consumer) the disaggregated consumption of its consumer and also provide relevant analysis linked to the energy behaviour (like when the different assets are functioning, abnormal behaviour of the assets or the assets that consumes the most) and energy efficiency of the assets.

Basic Path: Disaggregation at the backoffice

Step No.	Event	Description of process/ Activity	Info. exchanged	Actor producing the information	Actor receiving the information

1	Periodic	Data gathering	Home electrical measurements (aggregated)	Consumer (Smart meter)	AMI
2	Periodic	Data storage	Home electrical measurements (aggregated)	AMI	NILM module
3	Periodic	Energy Disaggregation	Home electrical measurements (disaggregated)	NILM module	EMS ESCO Consumer
Basic paths: Disaggregation at the edge					
Step No.	**Event**	**Description of process/ Activity**	**Info. Exchanged**	**Actor producing the information**	**Actor receiving the information**
1	Periodic	Data storage	Home electrical measurements (aggregated)	Smart meter	Smart home gateway
2	Periodic	Energy Disaggregation	Home electrical measurements (disaggregated)	Smart home gateway	EMS ESCO Consumer

Realization	
Main responsible partners (Author)	- ETRA
Contributing partners	- IMPULSA - AMIBIT - AEM - HIVE
Priority	High

UC 1.3	**Utilization of deep learning for state estimation**
Description	State estimation in OPENTUNITY will consist in solving an optimization problem that processes the available reliable measurements of the network along with the network topology in order to determine the most accurate estimation of the system state. This Use Case is relevant in a scenario where there are measurement losses or measurement errors. The output of state estimation is typically the voltage magnitude and phase (phase-to-ground voltage phasors) at all the network buses. If the voltage phasors are computed, then - for a given network topology, it is possible to compute all other parameters of interest, such as the power injections and power flows, the current injections and flows, the power losses, etc. Going beyond traditional mechanisms, this OPENTUNITY's state estimation will use deep learning to model complex relations among the measurements, also including time-series analysis and exogenous variables like calendar, weather prediction, etc.

Actors involved	- DSO - Prosumer. - EMS (Grid Energy Management System) - Weather forecast provider
Triggering Event	Need of the DSO to know the power flows of its grid but DSO does not have full metering of the grid.
Pre-condition	- Size and distribution of DER (including meter info). - Available network model: bus-branch configuration (topology), bus (generation/ load, installed capacity etc.) and branch parameters (line impedance, shunt elements etc.). - Access to (near) real-time measurement data gathered from the field: conventional (voltage magnitude, power flows/ injections delivered by SCADA/ RTUs, smart meters etc.) and synchronized (voltage/ current phasors recorded by PMUs). - Access to weather data (temperature, sunlight), also desired.
OPENTUNITY innovations involved	Topology identification and state estimation via machine learning.
Post-condition	DSO is able to have observability of the power flows of the selected lines. Acknowledgement by the DSO

Basic Path

Step No.	Event	Description of process/ Activity	Info. exchanged	Actor producing the information	Actor receiving the information
1	Periodic	Acquisition of real-time measurement/ information data	Grid measurements	DSO (SCADA, PMUs, relays, etc.)	EMS
2	Periodic	Acquisition of real-time measurement/ information data	DER measurements	Prosumer (Smart meters)	EMS
3	Periodic	Weather forecast gathering	Weather forecast	Weather forecast provider	EMS
4	Periodic	Solution to the State Estimation problem based on deep learning	Estimated network operating state (nodal voltage phasors)	EMS	DSO
5	Acknowledgement by the DSO	Response of DSO to the SE software that the real-time estimate of the network state is obtained and ready to be used	A confirmation message	DSO	EMS

		by other EMS functions			

Exception paths

Step No.	Event	Description of process/ Activity	Info. Exchanged	Actor producing the information	Actor receiving the information
1a	Data integrity check failed	Detection of missing or inconsistent data, gross errors (outliers) etc. in the available dataset.	Error message including the bad or missing data identified.	EMS	DSO

Realization	
Main responsible partners (Author)	- ETRA - ICCS
Contributing partners	- ANELL - EP - EL - AEM - SUPSI - HEDNO
Priority	High

UC 1.4	**Real-Time Thermal Rating (RTTR) for capacity calculation of MV lines**
Description	DSOs that do not use Real-Time Thermal Rating use static ratings for their lines, which can be conservative estimation of the capacity calculated for severe summer weather conditions. Real-Time Thermal Rating (RTTR) or Dynamic Line Rating (DLR) of overhead lines uses the fact that the line rating is constantly changing according to various factors (mainly related to weather conditions such as wind speed, wind direction, solar radiation and ambient temperature). The RTTR software will collect present data from available sensors belonging to the distribution system and forecasts of weather data to compute through an indirect approach the RTTR. The benefits from this Use Cases are: • Detecting congestion in the power system, • Avoiding RES curtailment, • Improving cost efficiency of the lines, • Avoiding investment in new lines.
Actors involved	• DSO • Energy Management System (from Distribution system and from buildings) • Weather Forecast provider
Triggering Event	Data of assets required to perform RTTR on a line are retrieved every 15 minutes

Pre-condition	• Available geodata of the overhead line (latitude/longitude of poles). • Available Conductor data (product name, cross section, resistance at 20 Celsius, maximum temperature, existing current rating). • Access to weather data forecasts (ambient temperature, wind speed/direction). • Access to real time data (15 minute granularity) of line current. • Access to real time data (15 minute granularity) from available temperature, wind speed/direction and irradiation sensors. • Access to real time data (15 minute granularity) of conductor temperature for validation purposes.
OPENTUNITY innovations involved	Low-cost real-time thermal rating.
Post-condition	The DSO acknowledges that the timeseries of the estimated temperature and dynamic current rating of the overhead lines provided by the RTTR software, has been received.

Basic Path

Step No.	Event	Description of process/ Activity	Info. exchanged	Actor producing the information	Actor receiving the information
1	RTTR software access to weather data	Time series of weather forecasts for the defined horizon of RTTR software.	Wind speed, Wind direction, ambient temperature, irradiation	Weather Forecasts Provider	DSO (RTTR software)
2	RTTR software access to real time data from Distribution system operator SCADA	Real time measurements (line current, power production of RES units in proximity, weather data sensors) with granularity of 15 minutes required for the RTTR calculation of the line under test.	Line Current, Active Power production of RES, Wind speed, Wind direction, ambient temperature, irradiation	DSO (SCADA)	DSO (RTTR software)
3	RTTR software access to real time weather data from building EMS	Real time weather measurements from building EMS near to the line, if any.	Ambient Temperature	EMS (Building)	DSO (RTTR software)
4	RTTR software updates the line thermal rating.	RTTR timeseries for existing and future conditions are calculated	Current Rating, Temperature	DSO (RTTR software)	DSO

		and transmitted to the DSO.			
5	Acknowledgement by the DSO	The DSO responds to the RTTR software that the RTTR timeseries are updated in its database.	Confirmation	DSO	DSO (RTTR software)

Exception paths

Step No.	Event	Description of process/ Activity	Info. Exchanged	Actor producing the information	Actor receiving the information
1a	Weather Data Forecasts are not available	The weather data forecasts are not available for the specified time periods, or the weather provider database cannot be accessed.	RTTR software produces error message describing the cause of weather forecasts	DSO (RTTR software)	DSO
1b	Real Time data are not available	Specific real time data provided by the DSO EMS or a building EMS are not available.	RTTR software produces error message describing which asset data are missing	DSO (RTTR software)	DSO

Realization

Main responsible partners (Author)	- ICCS - ETRA
Contributing partners	- ANELL - HEDNO
Priority	High

UC 1.5	**Advanced Asset Management**
Description	The objective of Advanced Asset Management will start with the identification of critical components and the associated risk index, namely the type of failure each component may have. This initial assessment of the critical components will also focus on the necessary data availability. Next, the task will focus on the development of ageing and failure models for different time scales (operation or planning). The core of these algorithms will be based on advanced machine learning and big data analytics algorithms. The advanced asset management software will use (nearly) real-time data acquired from SCADA and AMI platforms, historical data and logs (events) records for pretraining and fine-tuning tasks, in order to predict potential failures at different time horizon. The next step involves training the machine learning models using the available data.

	When executed, the software of Advanced Asset Management will be used to predict potential failures in critical components of the power system at different time horizons, from short-term to long-term.
Actors involved	• TSO • DSO • Energy Management System
Triggering Event	DSO/TSO request for software execution.
Pre-condition	• Access to historical data of failures and type of failures at least over the last 5 years. • Access to historical data on voltage & current with maximum granularity of 1 hour for at least 5 years of data. • Topological data (geodata of the location of equipment, description of installation (e.g. indoor, outdoor, pole mounted) • Access to historical data of inspection/maintenance • Access to equipment data (product name, type, characteristics) • Access to historical weather data
OPENTUNITY innovations involved	Advanced asset management
Post-condition	The DSO/TSO acknowledges that the Asset failure indication in the short/long term horizon of the requested assets provided by the AAM software, has been received.

Basic Path

Step No.	Event	Description of process/ Activity	Info. exchanged	Actor producing the information	Actor receiving the information
1	Request for software execution	DSO/TSO requests for a prediction of failure in a planning or operational horizon for specific assets or the cluster of assets in a part of the grid	Asset ID or cluster of Assets ID, Period of Forecast of Failure (Short term/Long Term)	DSO/TSO	DSO/TSO (AAM software)
2	Data acquisition for DSO/TSO AMI	Provision of data required to the advanced asset management software according to the desired horizon (short term/long term) by the DSO/TSO.	Historical data of current, voltage, failures, inspection, in csv format send by the DSO. No need for real time access for historical data. (Long term)	DSO/TSO	DSO/TSO (AAM software)

			Near real time data of current, voltage related to the assets selected by the DSO with granularity of maximum 1 hour (short term)		
3	Data acquisition from weather data provider	Provision of weather data required by the advanced asset management software for short- or long-term prediction of failures are provided by a weather provider like GFL or ECMWF.	Historical weather data (Long term) Weather Data Forecasts (short term)	Weather Data Provider	DSO/TSO (AAM software)
4	Data export by the Advanced Asset Management software	Present an overview of the prediction of asset failure according to the horizon requested by the DSO.	Asset failure indication in the short/long term horizon.	DSO/TSO AAM software	DSO/TSO
5	Acknowledgement by the DSO/TSO	The DSO/TSO responds a verification message, to the Advanced Asset Management software.	Confirmation	DSO/TSO	DSO/TSO (AAM software)

Exception paths

Step No.	Event	Description of process/ Activity	Info. Exchanged	Actor producing the information	Actor receiving the information
1a	Historical Current, voltage, failure data missing	Historical data are not available to perform long/short term asset management.	Advanced asset management software produces error message.	DSO/TSO (AAM software)	DSO/TSO
1b	Weather data missing	Real time or historical data are not available from the weather data provider	Advanced asset management software produces error message.	DSO/TSO (AAM software)	DSO/TSO

Realization

Main responsible partners (Author)	- ICCS - ETRA
Contributing partners	- HEDNO - ANELL - EL - IPTO - EP
Priority	High

UC 1.6	**Topology identification**
Description	This Use Case focuses on performing a network topology processing for distribution networks. In this Use Case, the network operator does not have a complete knowledge about the line infrastructure and needs to understand how the components of the network are interconnected. The aim is to determine both the connections and line impedances. This will allow to Identify power supply interruptions so that operators can quickly and efficiently address them.
Actors involved	- DSO - AMI (Advanced metering infrastructure). - Grid EMS (Energy Management System) - Consumers
Triggering Event	DSO needs to know how the components of the network are interconnected.
Pre-condition	• Available network parameters: potential bus-branch configurations (topology), bus (generation/ load, installed capacity etc.) and branch parameters (line impedance, shunt elements etc.). • Access to (near) real-time measurement data gathered from the field: conventional (voltage magnitude, power flows/ injections delivered by SCADA/ RTUs, smart meters etc.) and/or synchronized (voltage/ current phasors recorded by PMUs). • Access to real-time information data about the condition of switching devices of the network (open, closed or unknown).
OPENTUNITY innovations involved	Topology identification and state estimation via machine learning.
Post-condition	DSO is able to see which the current topology of its infrastructure is. Both the connections and line impedances are estimated. Acknowledgement by the DSO.

Basic Path

Step No.	Event	Description of process/ Activity	Info. exchanged	Actor producing the information	Actor receiving the information

1	Periodic	Acquisition of real-time measurement/ information data	Conventional and synchronized measurements, condition of switching devices, network parameters	DSO (SCADA, PMUs, relays etc.))	EMS
2	Periodic	Acquisition of real-time measurement/ information data	Home measurements	Consumers (Smart meters)	AMI
3	Periodic	Data gathering	Home measurements	AMI	EMS
4	Estate Estimation software data processing and output	Solution to the topology identification problem	Estimated network model (condition of switching devices)	EMS	DSO
5	Acknowledgement by the DSO	Response of DSO to the NTP software that the real-time estimate of the network model is obtained and ready to be used by the SE software or other functions	A confirmation message	DSO	EMS

Exception paths

Step No.	Event	Description of process/ Activity	Info. Exchanged	Actor producing the information	Actor receiving the information
1a	Incomplete data input	Detection of missing data in the available dataset.	Error message including the missing data identified.	EMS	DSO

Realization

Main responsible partners (Author)	- ETRA - ICCS
Contributing partners	- EP - EL - AEM - SUPSI - HEDNO
Priority	High

UC 1.7	Investment Deferral considering flexibility
Description	The goal of the algorithm is to defer distribution network investments by identifying the most cost-effective mix and location of flexibility such as RES, energy storage and demand response. By optimizing the size and location of these options, the algorithm aims to achieve the best investment deferral outcomes while maintaining the reliability and stability of the power system. The steps of the UC are: Collection of data: Collect data from various sources such as historical usage data, load forecasts, and energy market data. Furthermore, topology data from the specific MV lines are needed as well as the long-term failure indications of assets from UC 1.5. Develop models for investment deferral: Develop models using advanced optimization techniques to identify the most cost-effective mix and location of flexibility to defer network investments. Incorporate uncertainty and risk analysis: In order to evaluate the impact of different scenarios, such as changes in load forecasts, energy prices, or policy decisions.
Actors involved	• DSO
Triggering Event	DSO request for execution of the investment deferral algorithm
Pre-condition	• Historical measurements of RES, Load, Energy prices of at least 5 years with hourly granularity. • Topology of the grid • Location and capacity of existing and future RES plant on grid topology • Expected end of life of distribution system assets provided by asset management tool.
OPENTUNITY innovations involved	Grid planning methodologies.
Post-condition	Present to the DSO an overview of the status of the most cost-effective mix and location of flexibility

Basic Path

Step No.	Event	Description of process/ Activity	Info. exchanged	Actor producing the information	Actor receiving the information
1	DSO defines the part of the distribution system to run the innovation.	The DSO provides topological data on the part of the distribution system that the investment deferral algorithm will run.	Topology of the part of the distribution grid. Operational thresholds on voltage and current.	DSO	DSO (investment deferral tool)

2	Historical electrical data.	The DSO provides historical data from metering equipment on consumers, RES plants and the distribution system, in the considered part of the distribution system. The data from the meters, would be, wherever possible with hourly resolution.	Active and reactive power of demand, active power generation of RES units Active, reactive (if available) power.	DSO	DSO (investment deferral tool)
	Electricity prices Data	Historical electricity prices will be provided by an online platform with hourly resolution.	Electricity prices.	Online platform	DSO (investment deferral tool)
3	Long term load forecast and the RES potential estimation	Long term load forecasts and RES power potential will be computed based on historical data.	Annual power timeseries with hourly resolution.	DSO (investment deferral tool)	DSO (investment deferral tool)
4	Expected end of life of distribution system assets acquisition	UC 1.5 will provide the expected end of life of distribution system assets.	End of life in years of distribution grid assets.	DSO (advanced asset management tool)	DSO (investment deferral tool)
5	Computation of optimal flexibility mix	Optimization algorithm is executed, The most cost-effective mix and location of flexibility is computed.	Hourly Commitment of flexibility	DSO (investment deferral tool)	DSO (investment deferral tool)
6	Data visualization - data export. Present an overview of the results.	Present an overview of the status of the solution of the optimization algorithm.	Brief report with aggregated annual results, zip folder with csv files for each year containing hourly results	DSO (investment deferral tool)	DSO

Exception paths

Step No.	Event	Description of process/ Activity	Info. Exchanged	Actor producing	Actor receiving

				the information	the information
1a	Historical data on Load/RES/energy prices missing	Fail status displayed in the investment deferral software.	Message is displayed to inform the user to fill the missing data	DSO (investment deferral tool)	DSO
1b	End of life of distribution asset data missing.	Fail status displayed in the investment deferral software.	Message is displayed to inform the user to fill the missing data	DSO (investment deferral tool)	DSO

Realization	
Main responsible partners (Author)	- ICCS
Contributing partners	- HEDNO, - EL - EP - ETRA
Priority	High

UC 1.8	**HEMS/BEMS DR optimization and local flexibility management**
Description	OPENTUNITY HEMS/BEMS **flexibility management system** (BFMS) is a cloud-based system responsible for the local flexibility management and the participation of the demo sites in Demand Response services. It consists of **several software backend systems** developed in a modular approach to provide specific functionalities and flexibility management over various building assets (i.e., HVACs, DHWs, EVs including charging points, storage, and other assets) for effectively unlocking and exploiting the distributed small-scale flexibility potential behind every residential/building connection point. HEMS/BEMS flexibility management system provides day-ahead (24h) flexibility forecasts - possibility for upwards or downwards regulation of a building/asset consumption - based on the existing energy resources inside the pilot premises and will co-optimize the operation of several appliances to deliver maximum flexibility without violating end-users' comfort boundaries. To achieve this goal, several optimization engines are embedded in the core functionalities of the flexibility system. Extracted flexibility forecasts will be provided to the main market actors including aggregators and the NODES' local flexibility markets through the proper interfaces and according to predefined or standardized flexibility semantics. Upon a flexibility request from the DR market actors, HEMS/BEMS flexibility integrated control system will respond by generating optimal control actions in order to deliver the requested load dispatching while monitoring the assets' consumption and the overall performance of the dispatched control signals. The final activation of the

	building assets will be performed through the local controllers within the pilot buildings.
Actors involved	• Aggregator • EMS (from Buildings) • Prosumer • Flexibility Service Provider (FSP) • Flexibility Market Operator (FMO) • DSO
Triggering Event	• Requests for flexibility forecasts/profiles • Flexibility requests for load dispatching.
Pre-condition	• Demo sites are equipped with HEMS/BEMS. • Available energy resources inside the pilot premises to operate as flexibility assets. • Integration of the backend systems with the deployed solutions inside the pilot sites • Existence and communication with the local controllers/actuators within the pilot buildings. • Existence and data acquisition from the metering & sensing devices installed within the pilot buildings. • Interfacing with the market actors • Building asset information retrieval for the plug 'n' play recognition system
OPENTUNITY innovations involved	HEMS and BEMS Flexibility and DR optimization including initial settings algorithms
Post-condition	Provide flexibility forecasts upon requests and respond to any flexibility request for load dispatching.

Basic Path

Step No.	Event	Description of process/ Activity	Info. exchanged	Actor producing the information	Actor receiving the information
1	Flexibility forecasts extraction	The flexibility management system identifies flexibility potential from various assets	Power metering data, indoor conditions sensing data & monitoring info from the assets	EMS	BFMS
2	Flexibility forecasts delivery	Extracted flexibility forecasts are sent to the market actors	Flexibility forecasts	BFMS	Aggregator, FMO, DSO
3	Flexibility request	Market actors send the flexibility requests for load dispatching based on provided forecasts	Flexibility request details (e.g., timing, required load dispatching)	Aggregator, FMO, DSO	BFMS
4	Flexibility response	Backend flexibility manager control system generates optimal control	Dispatched control actions, asset consumption,	BFMS	EMS/Local controllers

		actions to deliver the requested load dispatching	performance monitoring		within pilot buildings
5	Building asset activation	Local controllers within pilot buildings activate the building assets	Control actions	EMS /Local controllers within pilot buildings)	Building assets
6	Flexibility request acknowledgement	HEMS/BEMS flexibility management system sends an acknowledgement of dispatched flexibility	Acknowledgement information	BFMS	Aggregator, FMO, DSO
Exception paths					
Step No.	**Event**	**Description of process/ Activity**	**Info. Exchanged**	**Actor producing the information**	**Actor receiving the information**
1a	Forecasted Flexibility not dispatched	End-user bypassed the dispatched control actions		End-user	BFMS
Realization					

Main responsible partners (Author)	- HYP
Contributing partners	- ETRA - UL - HEDNO - EYPESA - IMPULSA - JR - NODES - SETUP - AMIBIT - EP - AVANTCAR - EL - BLUE - AEM - HIVE - SUPSI
Priority	High.

UC 1.9	**Initialization of HEMS/BEMS Demand Response strategy**
Description	End-users' comfort constraints must not be violated during the operation of the HEMS/BEMS systems while their participation in Demand Response campaigns should not interfere with their preferences and affect their daily routine. Therefore, the end-users are in the centre of the solution by actively participating in the system configuration during the initial phase of the demonstration activities. On the other hand, they can also bypass any control actuation on their own assets during the demand response campaigns.

	During HEMS/BEMS flexibility management system initialization the end-users will scan the QR codes of their meters and energy assets for including their desired flexibility assets and also answer some simple questions through a user-friendly way for indicating their comfort preferences and daily schedules. All their inputs will be evaluated for understanding their DR capabilities and the degree of involvement in the DR campaigns. In addition, the initial settings algorithms will be triggered for fine-tuning the system and introducing the proper constraints in the optimization framework so that it can automatically generate demand response profiles and set the control optimization strategy without affecting the end-users. Many stakeholders will benefit from this innovation since they will have access to low volumes of flexibility usually occurring during peak hours but with high potential for large-scale aggregation.
Actors involved	• BFMS • Prosumer
Triggering Event	• End-user participation • Received QR codes from the Plug 'n' play recognition system
Pre-condition	• Interface with the installed HEMS/BEMS systems • End-user Engagement • Integration with the Plug 'n' play recognition system
OPENTUNITY innovations involved	HEMS and BEMS Flexibility and DR optimization including initial settings algorithms. Plug and play recognition for flexibility devices.
Post-condition	• Flexibility assets identification per prosumer • Generation of targeted Demand Response profiles • End-User comfort preservation

Basic Path

Step No.	Event	Description of process/ Activity	Info. exchanged	Actor producing the information	Actor receiving the information
1	Identification of flexibility assets & Flexibility Management System configuration	End-users scan QR codes of their meters and energy assets. Internal system configuration based on the information retrieved from the flexibility assets. Depending on the collected data different modelling approaches and configuration settings will be applied.	QR code information	Plug 'n' play recognition system,	BFMS

2	Initialization of comfort preferences	End-users share their comfort preferences and daily schedules	Comfort boundaries, daily schedules	Prosumer (HEMS/BEMS)	BFMS
3	Optimization framework formulation	Initial settings algorithms formulate the optimization framework and introduce the appropriate constraints based on the end-users' inputs regarding comfort preferences & daily schedules but also based on info retrieved by the scanned QR codes,	Flexibility asset data, Comfort boundaries, daily schedules	BFMS	BFMS
4	Demand response profiles	Generation of targeted, comfort-based demand response profiles	Flexibility forecasts	BFMS	Prosumer (HEMS/BEMS) Aggregator, FMO, DSO

Realization	
Main responsible partners (Author)	- HYP
Contributing partners	- ETRA - JR - AVANTCAR - BLUE - EP - EL - AEM - IMPULSA
Priority	High.

UC 1.10	**Establishment of a flexibility market and flexibility procurement**
Description	A flexibility market provides access to distributed flexibility assets across all grid levels. The implementation of a flexibility market can be site-specific considering national and regional characteristics in terms of TSO-DSO coordination, type of assets and asset availability, the prevailing grid problem and available devices and data. The flexibility provided may serve for the purpose of congestion management, grid balancing or voltage control and may be traded over short-term and long-term periods. The basic set up requires the presence of buyers (system operators) and sellers (Flexibility Service Providers/Aggregators). The market enables the exchange of the relevant information for each specific grid problem via buy/sell orders and associated baselines and metering data for validation and settlement.
Actors involved	- Flexibility Market Operator

	- Aggregator/FSP (Energy Management system) - Prosumers - DSO - TSO (optional)
Triggering Event	- Grid services using flexibility from the LV/MV grid
Pre-condition	- Aggregator/FSP: HEMS/BEMS + Remote control of assets of prosumers - SOs: Grid constraints (present/future) - Prosumers (ideally large variety of assets) - Data availability, ie. Metering data for baselining and potentially validation - Compatible data storage and exchange technology (optional for initial phase)
OPENTUNITY innovations involved	Flexibility market design and management. Topology identification and state estimation via machine learning.
Post-condition	Successful implementation of flexibility market(s) and integration into daily operational routine. Flexibility from the LV/MV is activated via NODES market to effectively solve grid constraints.

Basic Path

Step No.	Event	Description of process/ Activity	Info. exchanged	Actor producing the information	Actor receiving the information
1	Registration DSO/TSO	Registration SOs as clients Registration of their license area	Company details & frame of license area	System operators	NODES
2	Registration Grid nodes/grid structure	Replication of the grid using grid nodes; the granularity of details to be selected by DSO	Grid node structure	DSO	NODES
3	Registration FSP/Aggregator	Registration as client on NODES market	Company details	FSPs/Aggregators	NODES
4	Registration of Assets	Flexibility assets to be registered on NODES market platform	geographical coordinates, IC + meterpoint ID	FSPs/Aggregators	NODES/DSO
5	Assignment of assets to grid nodes	DSOs will be notified upon every new registered asset and assigns it to a grid node	Grid node location	DSO	NODES/FSPs/Aggregators

6	Order submission	DSOs, FSPs and Aggregators submit orders to indicate buy/sell interest of flexibility	Location, flexibility volume, price	DSO, FSPs, Aggregators	NODES, DSOs, Aggregators/FSPs
7	Baselines	FSPs/Aggregators must submit baselines/portfolio	Load/production profile without flexibility activation	FSPs/Aggregators	NODES
8	Meter data	DSO provides meter data for validation purposes	Meter data	DSO	NODES
9	Validation	Monitoring of physical delivery of flexibility	Baselines and meter data	NODES	DSO/FSP/Aggregator

Realization	
Main responsible partners (Author)	- NODES
Contributing partners	- ETRA - ICCS - HYP - HEDNO - ANELL - IMPULSA - IPTO - AEM
Priority	Medium

11.2.2 GREECE

UC 2.1	**Network planning for High RES penetration**
Description	The objective of this UC is to determine the most suitable upgrades in the MV network to enhance the penetration of RES. The steps of the UC are: Collect data: The algorithm will require the existing network topology, the current RES, and the potential for further RES deployment. The availability of flexibility from RES and distributed generators (DGs) will also be taken into account. Furthermore, topology data from the specific MV lines are needed as well as the long-term failure indications of assets from UC 1.5.

	Develop models for network planning: Develop models using advanced optimization techniques to identify the most cost-effective actions to enhance the penetration of RES.
Actors involved	• DSO
Triggering Event	DSO request for execution of the Network planning for High RES penetration algorithm
Pre-condition	• Historical measurements of RES, Load of at least 5 years with hourly granularity. • Topology of the grid • Location and capacity of existing and future RES plant on grid topology • Expected end of life of distribution system assets provided by asset management tool.
OPENTUNITY innovations involved	Grid planning methodologies.
Post-condition	Present to the DSO an overview of the most cost-effective actions to enhance the penetration of RES

Basic Path

Step No.	Event	Description of process/ Activity	Info. exchanged	Actor producing the information	Actor receiving the information
1	Past System Data acquisition	Past system data of peak and annual demand and RES production with hourly resolution.	Active and reactive power of demand, active power generation of RES units	DSO	DSO (network planning tool)
2	Long term load forecast and the RES potential estimation	Long term load forecasts and RES power potential will be computed based on historical data.	Annual power timeseries with hourly resolution.	DSO (network planning tool)	DSO (network planning tool)
3	Expected end of life of distribution system assets acquisition	UC 1.5 will provide the expected end of life of distribution system assets.	End of life in years of distribution grid assets.	DSO (advanced asset management tool)	DSO (network planning tool)
4	Computation of optimal planning actions mix	Optimization algorithm is executed, The most cost-effective actions to enhance the penetration of RES	Hourly Commitment of flexibility, Network upgrade actions	DSO (network planning tool)	DSO (network planning tool)
5	Data visualization - data export. Present an	Present an overview of the status of the solution of the	Brief report with aggregated annual results, zip folder with csv files for each year	DSO (network planning tool)	DSO

	overview of the results.	optimization algorithm.	containing hourly results		

Exception paths

Step No.	Event	Description of process/ Activity	Info. Exchanged	Actor producing the information	Actor receiving the information
1a	Historical data on Load/RES/energy prices missing	Fail status displayed in the investment deferral software.	Message is displayed to inform the user to fill the missing data	DSO (network planning tool)	DSO
1b	End of life of distribution asset data missing.	Fail status displayed in the investment deferral software.	Message is displayed to inform the user to fill the missing data	DSO (network planning tool)	DSO

Realization

Main responsible partners (Author)	- ICCS
Contributing partners	- HEDNO - ETRA
Priority	Medium

11.2.3 SLOVENIA

UC 3.1	**Baseline and flexibility forecast for EV fleet**
Description	The objective of this Use Case is to provide baseline and flexibility forecast for the charging of the EV fleet owned by AVANTCAR. This data will be used as input for optimal selection of available flexibility algorithm (UC 3.3). The algorithm will make use of the historical charge data, EV data, weather data (additional data sources will be defined in the scope of the implementation, if needed) and form different charging point (CP) profiles to determine the flexibility potential of the EV fleet in a given time of day. The algorithm will consider different types of CP (e.g. CP used for car-sharing, over-night CP…).
Actors involved	• Aggregator (Kolektor sETup) • EV Fleet Manager (AVANTCAR)
Triggering Event	The algorithm will run constantly and automatically and will provide new values every 15-min (interval could be adjusted in later stages based on the needs), based on the new measurement values from the CPs. The aggregator will then be able to update its baseline forecast.
Pre-condition	• Each integrated CP will provide necessary data for the forecasting algorithm. • Collection of the data and forecasting algorithm will be hosted on AVANTCAR platforms (individual CP).

OPENTUNITY innovations involved	HEMS and BEMS Flexibility and DR optimization including initial settings algorithms. Optimal selection of available flexibility
Post-condition	The aggregator platform receives: • Flexibility and baseline forecast for the EV fleet**.** • Flexibility price. • Maximum activation duration time of specific CP (how long can it provide flexibility at certain power). • Set point change (ON/OFF, step etc.).

Basic Path

Step No.	Event	Description of process/ Activity	Info. exchanged	Actor producing the information	Actor receiving the information
1	AVANTCAR platform receives data	Various data is received (EV charging station data, activation data, etc), which is an input for the forecasting algorithm	-Power measurements (current and historic values) -type of charging station -car data (if possible SoC, -weather forecast	EV charging stations, aggregator	EV fleet manager (more precisely their platform)
2	The forecast algorithm activates/runs	After receiving input data, the forecast algorithm is triggered. The algorithm calculates baseline and flexibility based on the available data.	/	EV fleet manager (more precisely their platform)	EV fleet manager (more precisely their platform)
3	Forecast sent to the aggregator platform	The resulting forecasts for both baseline and flexibility potential is sent to the KOL aggregator platform.	-Baseline and flexibility forecast -flexibility price -maximum activation duration time of specific CP -set point change (ON/OFF, step etc.)	EV fleet manager (more precisely their platform)	Aggregator

Exception paths

Step No.	Event	Description of process/ Activity	Info. Exchanged	Actor producing the information	Actor receiving the information

Realization	
Main responsible partners (Author)	-UL
Contributing partners	-SETUP -AVANT
Priority	High

UC 3.2	Baseline and flexibility forecast for HEMS fleet
Description	The objective of this Use Case is to provide baseline and flexibility forecast for the HEMS fleet owned by AMIBIT. This data will be used as input for optimal selection of available flexibility algorithm (UC 3.3) For HEMS flexibility, the forecast will take into account the types of devices, weather data and comfort of the end-user (additional data sources will be defined in the scope of the implementation, if needed), which are connected to the Reduxi unit and output the information needed for optimal selection algorithm to work (we will need the baseline for different time intervals, flexibility, price of flexibility, duration of active time of an asset and set point change). Each individual Reduxi unit will provide baseline and flexibility forecast to the KOL aggregator platform. The forecasting algorithm will take into account both initial settings algorithm and historical measurement data.
Actors involved	• Aggregator (Kolektor sETup) • HEMS system manager (AMIBIT)
Triggering Event	The algorithm will run constantly and automatically and will provide new values every 15-min, based on the new measurement values from the Reduxi unit. The aggregator will then be able to update its baseline forecast.
Pre-condition	• Each integrated Reduxi will provide necessary data for the forecasting algorithm. • Collection of the data and forecasting algorithm will be hosted on AMIBIT platforms (individual Reduxi devices).
OPENTUNITY innovations involved	HEMS and BEMS Flexibility and DR optimization including initial settings algorithms. Optimal selection of available flexibility
Post-condition	The aggregator platform receives: • Flexibility and baseline forecast for the HEMS fleet. • Flexibility price • Maximum activation duration time of specific Reduxi unit • Set point change (ON/OFF, step etc.).
Basic Path	

Step No.	Event	Description of process/ Activity	Info. exchanged	Actor producing the information	Actor receiving the information
1	The HEMS device receives weather forecast	Individual Reduxi HEMS device receives the (day-ahead) weather forecast from external source	Weather forecast inputs (temperature, solar irradiadiation)	External	Individual Reduxi HEMS
2	The forecast algorithm activates	Each separate Reduxi HEMS unit calculates baseline operation and flexibility forecast based on the types of devices connected to the Reduxi and weather forecast.	-Power measurements for individual devices (current and historic values) -types of devices connected to the Reduxi unit	Individual Reduxi HEMS	Individual Reduxi HEMS
3	The forecast information is sent to the aggregation platform.	The baseline operation and flexibility forecasts are sent to the aggregation platform, where it is used to offer it on the market and serves as an input for the optimal selection of available flexibility algorithm.	-Baseline and flexibility forecast -flexibility price -maximum activation duration time of specific CP -set point change (ON/OFF, step etc.)	HEMS fleet operator (AMIBIT)	Aggregator

Realization	
Main responsible partners (Author)	-UL
Contributing partners	-SETUP -AMIBIT
Priority	High

UC 3.3	**Optimal selection of available flexibility**
Description	The primary objective of this Use Case is to form the selection process for available flexibility sources. The selection process will be, in the scope of this project, based on flexibility from the Electric Vehicle (EV) fleet owned by AVANTCAR and the HEMS (Reduxi) fleet owned by AMIBIT. The algorithm should be conceptualized for expansion and the use of additional flexibility sources. This will be done by via an algorithm, which will be integrated into the aggregator platform (SETUP). The algorithm will be triggered after a bid sent to the market is accepted, with the requested activation time and power serving as inputs for the algorithm. Based on these a list of optimal devices is formed, and the aggregator sends the activation signal to these devices.

	In the scope of this project, the market signals will likely be simulated and this Use Case will aim to demonstrate the functionality of the optimal selection algorithm. The optimized selection process for flexibility sources in the EV and HEMS fleets benefits both the companies and the System Operators. By utilizing this flexibility, System Operators can avoid or defer costly network reinforcement measures, reduce congestion on the grid, and improve the stability and reliability of the local electricity grid. This enables System Operators to save costs and enhance the overall quality of service for customers by reducing the likelihood of power outages and other grid-related issues.
Actors involved	• Aggregator (Kolektor sETup) • EV Fleet Manager (AVANTCAR) • HEMS fleet manager (AMIBIT)
Triggering Event	The aggregator will offer the forecasted flexibility energy and/or capacity from AVANTCAR's EV fleet and AMIBIT's HEMS fleet on the ancillary service market.
Pre-condition	• The aggregator platform and EV fleet (EV charging stations) must be integrated/connected. • The aggregator platform and HEMS fleet (Reduxi units) must be integrated/connected. • EV and HEMS fleet baseline and flexibility forecast is provided.
OPENTUNITY innovations involved	Optimal selection of available flexibility
Post-condition	The optimal units from the EV and HEMS fleets are activated.

Basic Path

Step No.	Event	Description of process/ Activity	Info. exchanged	Actor producing the information	Actor receiving the information
1	Baseline and flexibility forecast is received	The aggregator platform receives baseline and flexibility forecast from the EV and HEMS fleets.	Baseline and flexibility forecast	EV and HEMS fleet operators	Aggregator
2	Bid sent to the market	Based on the flexibility forecast for EV and HEMS fleets (and other units in the aggregator's portfolio) the aggregator sends a bid to the market (TSO ancillary service market or other).	Bid information: -Capacity market (bid for power in kW for the whole day, flexibility direction – positive or negative) -Energy market (bid for power for every 15-min,	Aggregator	Market

			flexibility direction)		
3	Bid is accepted	If the aggregator's bid is accepted in certain time period, the market sends an activation signal to the aggregator's platform (most likely simulated).	Activation signal (most likely simulated) sent to the aggregator	Market	Aggregator
4	Aggregator runs optimal selection algorithm	After receiving the activation signal from the market, the aggregator runs the optimal selection algorithm with an input of activation power and time of the bid. The algorithm selects HEMS and EV units which satisfy these requirements (with additional factor being the price of the units – in that case the cheapest combination is selected).	List of optimal devices for activations	Aggregator	Aggregator
5	Activation of optimal units	Based on the results, the aggregator sends an activation signal to selected units, which activate according to it	Activation signal to the units	Aggregator	EV and HEMS fleet units

Exception paths

Step No.	Event	Description of process/ Activity	Info. Exchanged	Actor producing the information	Actor receiving the information
1a	Baseline and flexibility forecast is received	The aggregator platform receives baseline and flexibility forecast from the EV and HEMS fleets.	Baseline and flexibility forecast	EV and HEMS fleet operators	Aggregator
2a	Bid sent to the market	Based on the flexibility forecast for EV and HEMS fleets (and other units in the aggregator's portfolio) the aggregator sends a bid to the market (TSO ancillary service market or other).	Bid information: -Capacity market (bid for power in kW for the whole day, flexibility direction – positive or negative) -Energy market (bid for power for every 15-min, flexibility direction)	Aggregator	Market
3a	Bid is not accepted	Bid is not accepted	Rejected bid	Market	Aggregator

Realization	
Main responsible partners (Author)	-SETUP -UL
Contributing partners	-AVANTCAR -AMIBIT
Priority	High

11.2.4 SPAIN

UC 4.1	**Topology detection**
Description	This Use Case focuses on performing a topology analysis for distribution networks. In this Use Case, the network operator knows the line infrastructure and their impedances and needs to determine the ones that are currently energized. The aim is to confirm that the observed data from the topology corresponds to the topology assumed by the network operator and detect if there are discrepancies (errors, things that are connected where they should not and short-circuits) and locate faults.
Actors involved	- DSO - AMI (Advanced metering infrastructure). - EMS (Grid Energy Management System) - Consumers.
Triggering Event	DSO needs to determine the lines that are currently energized.
Pre-condition	- Static parameters of the grid. - SCADA measurements. - GIS access. - Measurements from other controllable devices (like RTU). - Voltage data from smart meters. - Voltage feeder information.
OPENTUNITY innovations involved	Topology identification and state estimation via machine learning.
Post-condition	DSO is able to double check if the assumed topology is correct and which are the energized lines.

Basic Path

Step No.	Event	Description of process/ Activity	Info. exchanged	Actor producing the information	Actor receiving the information
1	Periodic	Data gathering	Grid measurements	DSO (SCADA)	EMS
2	Periodic	Data gathering	Home measurements	Consumers (Smart meters)	AMI

3	Periodic	Data gathering	Home measurements	AMI	EMS
4	Periodic	Topology detection	Alarms/events for topology changes	EMS	DSO

Realization	
Main responsible partners (Author)	Add one or maximum two partners from this list: - ETRA
Contributing partners	- ANELL
Priority	Medium

UC 4.2	**Fraud detection (non-technical losses)**
Description	The main objective of this Use Case is to identify the potential theft attempts in order to illegally reduce their electricity bills. These attempts are made by reversing the meters, by-passing or slowing down the meters or inaccurate readings. In order to do so, it is required to recognize the consumption patterns of the consumers of electricity. OPENTUNITY will rank the end-users using a score of anomalous behaviour to each supply point using machine learning and big data techniques. This information can be further used by grid operator to schedule visual inspections of the end-user installations.
Actors involved	• Consumer • DSO • EMS (Grid Energy Management System)
Triggering Event	Weekly automatic check-up.
Pre-condition	• Good communication between smart meters and data concentrators • Data from end-users' smart meters • Data from supervisors at secondary substation level • Topology
OPENTUNITY innovations involved	Topology identification and state estimation via machine learning. Advanced asset management.
Post-condition	The grid operators receive an alarm whenever suspicious consumption patterns which may relate to a fraud are detected. They are given a location for the potential theft, with a radius up to 100-200 m, so that they're able to send out staff to further investigate.

Basic Path

Step No.	**Event**	**Description of process/ Activity**	**Info. exchanged**	**Actor producing the information**	**Actor receiving the information**
1	Data is received from field assets	EMS collects information from all field assets	Voltage Active Power Reactive Power	Consumer (Smart meters) DSO (Supervisors)	EMS

2	Data is evaluated	EMS's algorithms analyse energy consumption and voltage data and identifies suspicious patterns	Voltage Active Power Reactive Power	EMS	EMS
3	Alert for possible fraud	An alarm is sent via email (or other channels) to the responsible operator from the DSO	Energy consumption patterns Location of possible fraud Fraud type (plantation, residential)	EMS	DSO
4	Fraud assessment	After the DSO further investigated the case, it marks the alert as an actual fraud or false positive. If it's true, it provides further information on the fraud. The data are stored to be used in the future for training of the non-technical losses detection algorithm and for evaluation purposes.	Fraud confirmation	DSO	EMS
Exception paths					
Step No.	**Event**	**Description of process/ Activity**	**Info. Exchanged**	**Actor producing the information**	**Actor receiving the information**
2a	No suspicious behaviour is detected	When there are no suspicious consumption patterns, the algorithm stores the data.	Energy consumption patterns	EMS	DSO

Realization	
Main responsible partners (Author)	ANELL
Contributing partners	- ETRA - ICCS - ANELL
Priority	High

UC 4.3	Detection of unwanted or unexpected islands for PV panels
Description	In a normal operation of the grid, LV grid supplies consumers and prosumers. There's also the possibility that prosumers inject energy to the grid, although the grid is the one who maintains the quality of the electricity when PV generation is injected keeping the voltage under certain values of quality. However, in certain cases, the normal operation of a triphasic line, the equilibrium of the line gets disrupted when a fuse from one phase blows. When this happens, the grid can't manage the unbalance and it can happen that energy generated from the prosumer's PVs is consumed by a consumer in the same line and phase. As there is no control over this injection, this energy can be of poor quality, supposing a problem for other consumers. The aim of the Use Case is to detect the blown fuse through the monitoring of the voltage at end user level and an algorithm to undertake the calculations.
Actors involved	• DSO • EMS (Grid Energy Management System) • ESCO • Prosumer
Triggering Event	A significant change in the voltage phasor of certain Smart Meters connected to the same line, can be an indicative that a fuse has blown in one of the phases.
Pre-condition	Known topology of the grid and their phase's connections
OPENTUNITY innovations involved	Topology identification and state estimation via machine learning.
Post-condition	The algorithm detects the blown fuses without the necessity to install sensors and prior sets an alarm to the control centre with the exact location of the fault.

Basic Path

Step No.	Event	Description of process/ Activity	Info. exchanged	Actor producing the information	Actor receiving the information
1	Connectivity in nearly real time	The DSO keeps receiving information from the smart meters and sends it to the EMS	Voltage SM Voltage substation Active power Reactive power	DSO	EMS
2	Quality track of the grid	The EMS keeps track of the quality of the grid through the monitoring of the voltage	Voltage SM Voltage substations Active power Reactive power	EMS	EMS

3	Quality alteration	When an alteration in the voltage is detected, the data is processed to identify the pattern and the exact location of the fault	Type of fault Location	EMS	EMS
4	Alert provision	When the fault is identified, the alert sign is sent to the DSO as an alarm of blown fuse detected and the location to the DSO	Alarm Type of fault Location	EMS	DSO
Exception paths					
Step No.	**Event**	**Description of process/ Activity**	**Info. Exchanged**	**Actor producing the information**	**Actor receiving the information**
1a	Bad quality of connectivity	The channel of communication is saturated, and the concentrators are not receiving information from SM	-	DSO	EMS
3a	Fuse deterioration	When the fuse has suffered a deterioration and it has lowered its level of tolerance, it can happen that it blows at an apparently normal voltage or consumption peak, putting some difficulties to the detection of blown fuses.	Voltage SM Voltage substation Active power Reactive power		
Realization					
Main responsible partners (Author)	ANELL				
Contributing partners	- ETRA - ANELL				
Priority	High				

UC 4.4	**Detection of critical points in an electrical line**
Description	DSO's electrical lines can experience changes of section in the same line as it supplies clients and goes further away from the transformer. Since the section goes smaller and the penetration of PV for self-consumption and EV goes higher in unforeseen

	locations, there's a potential risk of congestion in parts of the line with lower section of cable. The aim of this Use Case is to simulate and detect these critical points in accordance with the capacity limits of the different cables in the same line, by creating different scenarios that stresses the grid.
Actors involved	• DSO • ESCO • EMS (Grid Energy Management System) • Consumer
Triggering Event	The request of connection of new clients or the forecast of installation of new PV or EV charging points starts a process of analysis of the grid's capacity.
Pre-condition	Topology of the grid with impedances and sections of cables Location of existing PV and EV installations
OPENTUNITY innovations involved	Topology identification and state estimation via machine learning.
Post-condition	Detect specific points in the grid where the inclusion of new capacity or new elements can suppose a big risk of congestion in a specific tram of the grid. Also, set limits in power of potential renewable installation in the critical trams of the grid.

Basic Path

Step No.	Event	Description of process/ Activity	Info. exchanged	Actor producing the information	Actor receiving the information
1a	Reception of new connection requests	Consumers provide new requests to access the grid to the DSO	Location Topology Contracted power/peak power	Consumer	DSO
2	Forecast of energy increase	The same DSO can make forecasts of PV and EV penetration to test their own grid	Topology Power	DSO	DSO
3	Creation of scenarios	The DSO starts a process of detecting the capacity of the grid by identifying several scenarios of stress in the grid	Cables information Topology Power	DSO	EMS
4	Calculation and results	The EMS calculates the results of the simulation and provides the exact location of the critical points, its maximum capacity, and alternative solutions of connection	Location Power Capacity	EMS	DSO

Realization	
Main responsible partners (Author)	ANELL
Contributing partners	- ETRA - ANELL
Priority	Medium

UC 4.5	**Improving the Grid Infrastructure**
Description	The Spanish redistributive model (the model followed to provide funding for DSOs) is becoming more and more selective. Even if it was not so, an investment must always be done in the smartest way possible, bringing the best possible outcome to the investor. Grid planning methodologies will assist the DSOs on planning their investments for improving the grid infrastructure, increasing RES integration and decarbonisation of the grid in the most cost-efficient manner.
Actors involved	• DSO • EMS (Grid Energy Management System)
Triggering Event	• New requests for access to the grid (new consumer, new prosumer, new producer) • Detected issues on the grid • Investments planning performed each year – planning in detail for the next year, and superficially for the following two
Pre-condition	• Cables information • Good communication between smart meters and data concentrators • Data from smart meters • Topology
OPENTUNITY innovations involved	Grid planning methodologies.
Post-condition	Outputs from several simulations from different possible scenarios, which allows us to identify possible bottlenecks and prioritize the investments to be made.

Basic Path

Step No.	Event	Description of process/ Activity	Info. exchanged	Actor producing the information	Actor receiving the information
1	DSO need for planning	DSO needs to plan for an investment, either for its regular activity or due to issues detected on the grid, or due to a new access request to the grid	Information on the new petition (requests for access, RES connections, EV charging points, power increase, etc)	DSO	EMS
2	DSO defines	DSO adds criteria/scenarios to	Information on the simulation	DSO	EMS

	scenarios to be tested	be tested on the different simulation. Some might be predefined on the platform, others added manually (and stored on the platform for later use)	scenarios (test different intervals of consumption, injection to the grid, possible failures, different locations, etc)		
3	EMS provides simulations output	After systematic simulations covering all the different scenarios, the simulation outputs are presented to the user. Potential bottlenecks are highlighted	Simulation output	EMS	DSO
4	Prioritisation	Simulations also determine which investments produce the best outcome and thus should be prioritised	Simulation output	EMS	DSO
Exception paths					
Step No.	**Event**	**Description of process/ Activity**	**Info. Exchanged**	**Actor producing the information**	**Actor receiving the information**
3a	Simulation does not converge	If a result is not found for all the criteria given, the user is asked to change certain parameters	Parameters to be changed	EMS	DSO
4a	Impossible to prioritise	If it is not possible to prioritise with the given information, the user is asked to give additional information/criteria	Additional parameters	DSO	EMS
Realization					
Main responsible partners (Author)	- ANELL				
Contributing partners	- ETRA - ICCS - ANELL				
Priority	Medium				

11.2.5 SWITZERLAND

UC 5.1	**Improve congestion management to facilitate DERs penetration**

Description	Despite the distribution system's resilient design, capable of accommodating various transfer capacities, the growing prevalence of Distributed Energy Resources (DERs), particularly solar photovoltaic systems, coupled with the rising energy demands in low voltage (LV) power supplies, is heightening the probability of congestion and overvoltage events. The following Use Case focuses on the creation and implementation of an active congestion management system capable of predicting and preventing congestions and overvoltages on the LV distribution grid leveraging the local available flexibility. By adopting Demand Side Management (DSM) techniques and incorporating cross-vector integration (e.g., Power-to-Heat and Power-to-Mobility), Renewable Energy Sources (RES) and flexible assets can be utilised and managed effectively to ensure greater grid efficiency and stability by reducing the occurrence of these events. List of advantages: • Defer costly investments for the Distribution System Operator (DSO) • Improve the overall system efficiency, resulting in reduced billing costs for end-users
Actors involved	• Consumer (CONS) • Prosumer (PROS) • Distribution System Operator (DSO) • Energy Management System (EMS – Building Energy Management System or Grid Energy Management System) • Flexibility Service Provider (FSP)
Triggering Event	• The proliferation of Distributed Energy Resources (Solar PVs) • The increasing in energy demand on the low voltage side
Pre-condition	• The presence of local generation (Solar PVs). • The availability of controllable assets for conducting Demand Response (DR) campaigns. • The existence of electric heating and cooling systems (Heat Pumps and Electric Boilers) and EV chargers in the territory that are either Smart Grid ready or easily controllable.
OPENTUNITY innovations involved	HEMS and BEMS Flexibility and DR optimization including initial DR settings algorithms Optimal selection of available flexibility Topology identification and state estimation via machine learning
Post-condition	The developed technology will enable the prediction and prevention of potential congestion and overvoltage events in the local distribution network of the energy community. This should be regarded as an investigative case. The ultimate goal of the Use Case is to develop a scalable solution, a Congestion Management tool that can be applied to larger distribution grids.

Basic Path

Step No.	Event	Description of process/ Activity	Info. exchanged	Actor producing the information	Actor receiving the information

1	TRAFO/GRID RATINGS	Forecast the status of trafo and local grid	Maximum currents, Voltage profiles	EMS (Grid Energy Management System)	DSO
2	FORECAST OF CONSUMPTION AND PRODUCTION	Forecast of consumption and production	Forecast of power injected/withdrawn	EMS (Grid Energy Management System)	DSO
3	FLEXIBILITY REQUIREMENT ESTIMATION	The DSO estimates the required flexibility to avoid congestions	Flexibility needed	EMS (Grid Energy Management System)	DSO FSP
4	IDENTIFICATION OF AVAILABLE FLEXIBILITY	The FSP identifies the available flexibilities by querying the EMSs	List of flexibilities based on location	EMS (Building Energy Management System)	FSP
5	FLEXIBILITY ACTIVATION	The FSP sends ctrl setpoints to EMS	Ctrl command	FSP	EMS (Building Energy Management System)
6	M & V	Measurement and validation. The measurements are collected (online)	Measurements of flexible resources	DSO, FSP	FSP, DSO

Realization	
Main responsible partners (Author)	AEM
Contributing partners	• SUPSI • HYP • UL • HIVE • ETRA
Priority	Medium

UC 5.2	**Integrate flexibility with the distribution grid to provide balancing services**
Description	In relation to the flexibility market, a highly relevant topic involves the potential aggregation of small Distributed Energy Resources (DERs) to offer flexibility services to the Distribution System Operators (DSOs) and entities operating in the ancillary service market, such as Balancing Service Providers (BSPs) The flexibility accessible from small renewable assets connected to the low voltage grid can be utilised either to

	directly influence individual feeders within the distribution grid (service to the DSO) or to be consolidated into larger volumes for services like grid balancing. The following Use Case considers as main validation case a service to the DSO, where the flexibility will be used to improve the health of the local distribution grid. A second optional validation case is also considered to investigate the possibility of integrating other buyers such as a BSP. The implementation and testing of the asset management control system will be carried out directly at the pilot site, while the management and operational aspects of the flexibility market will be simulated using real data from the energy community. List of advantages: • Enable small DERs owners to amortise their investment making the flexibility market more accessible and inclusive. • Present a cost-effective solution for providing local grid and balancing services to grid operators and energy companies. • Investigate an efficient solution for optimal management of energy surplus at the community level.
Actors involved	• Energy Management System (EMS) (Grid Energy Management System or Building Energy Management System) • Consumer (CONS) • Prosumer (PROS) • Distribution System Operator (DSO) • Flexibility Service Provider (FSP) • Flexibility Market Operator (FMO)
Triggering Event	The increasing relevance of the potential aggregation of small Distributed Energy Resources (DERs) to offer flexibility services in the flexibility market.
Pre-condition	• Presence of an Energy Community with small Distributed Energy Resources (DERs) connected to the low voltage grid. • Availability of controllable assets with flexibility to be offered as a service. • Participation of the Distribution System Operator (DSO) • Avoid loss of direct control by the end-user or the possible loss of comfort. • Development of an asset management and control system capable of identifying, selecting, and aggregating available flexibility. • Availability of data from the energy community for simulating the asset management and control system.
OPENTUNITY innovations involved	HEMS and BEMS Flexibility and DR optimization including initial DR settings algorithm AI non-intrusive load monitoring algorithms as a low-cost technology for sensorless prosumers.

	Optimal selection of available flexibility Flexibility market design and management Topology identification and state estimation via machine learning
Post-condition	• A cost-effective solution is presented for providing local grid and balancing services. • The algorithm is fully scalable to be extended to additional and larger Energy Communities. • The potential services that an energy community can provide in the flexibility market are explored. • The asset management and control system successfully identifies, selects and aggregates the flexibility available within the community and manages to make it available for market participation.

Main validation case (DSO): 1a → 2 → 5 → 6 → 7 → (8) → 9 → 10

Optional validation case (BSP): 1b → 2 → 3b → 4b → 5 → 6 → 7 → (8) → 9 → 10

Basic Path

Step No.	Event	Description of process/ Activity	Info. exchanged	Actor producing the information	Actor receiving the information
1a	FLEXIBILITY REQUEST	The DSO publishes a flexibility request on the flexibility market platform	Flexibility request	DSO	FMO
2	IDENTIFICATION OF AVAILABLE FLEXIBILITY	The FSP identifies the available flexibilities by querying the EMSs	Available flexibility	EMS (Grid Energy Management System)	FSP
5	FLEXIBILITY BIDDING	The FSP bids the available flexibility on the market platform	Flexibility offer	FSP	FMO
6	MARKET CLEARING	The FMO automatically clears the market by matching offer and demand	Flexibility prices and quantities	FMO	FSP, DSO/BSP
7	FLEXIBILITY ACTIVATION REQUEST	The FSP sends ctrl setpoints to EMS	Ctrl setpoint	FSP	EMS (Building Energy Management System)
9	FLEXIBILITY CONTROL	The EMS controls its flexibilities	Ctrl Command	EMS (Building Energy Management System)	FSP
10	M & V	Measurement and Validation. The measurements are collected and	Measurements of flexible resources	DSO	FMO

		validated using the blockchain			

Exception paths					
Step No.	**Event**	**Description of process/ Activity**	**Info. Exchanged**	**Actor producing the information**	**Actor receiving the information**
1b	FLEXIBILITY REQUEST	The BSP publishes a flexibility request on the flexibility market platform	Flexibility request	BSP	FMO
3b	VERIFY LOCAL GRID CONSTRAINTS	If flexibility is offered to BSP, FSP verifies with the DSO the maximum biddable flexibility (to avoid violating local grid constraints)	Maximum flexibility based on the location in the grid	DSO	FSP
4b	GRID CONSTRAINTS VIOLATION	Only if the FSP operating under flexibility violates grid constraints	Constraint violation	DSO	FMO
8	CTRL NOT ACTUATED	The control command is not actuated on the asset	Alert	EMS (Building Energy Management System)	FSP

Realization

Main responsible partners (Author)	AEM
Contributing partners	• SUPSI • HYP • UL • HIVE • ETRA • NODES
Priority	Medium

11.3 ANNEX III: LIST OF REQUIREMENTS

Table 38 - OPENTUNITY Requirements

ID	Description	Classification	Type	Rationale	Acceptance criteria	Priority	Comments	Author
AAM_001	Fraud detection algorithm within UC4.2 shall be able to detect areas where potential frauds are more probable.	Advanced asset management	The purpose of the product			5		EYPESA (Sara Vieira)
AAM_002	Availability of historical data on failures of equipment	Advanced asset management	Functional and data requirements	Failure rates trend of equipment can be an important indicator used in aging and failure models of equipment.	At least 5 year of data declaring for the equipment in the pilot, the occurance (or absence) of ailure and the reason of failure if exists.	5		ICCS (Dimitris Lagos)
AAM_004	Ageing model algorithms within UC1.5 shall be able to predict when an	Advanced asset management	The scope of the product			4		EYPESA (Sara Vieira)

	equipment should be replaced to avoid future faults.							
AAM_005	Fraud detection programme within UC4.2 shall send an alert everytime a suspecious activity/pattern is detected.	Advanced asset management	Users of the product			4		EYPESA (Sara Vieira)
AAM_006	Historical Electrical Data for algorithm training	Advanced asset management	Functional and data requirements	Historical data on voltage and currents (if available) of the asset under test	Granularity of 1 hour. At least 5 year of data.	3		ICCS (Dimitris Lagos)
AAM_007	Historical Data for algorithm training - Maintenance/Inspection Data	Advanced asset management	Functional and data requirements	Provision of data from inspection/maintenance that can be used for training.	Measurements or information from inspection with a respective timestamp for multiple time periods.	3	Non-Numeric data (e.g. condition based on visual inspection) should be categorical (e.g. good, average, bad)	ICCS (Dimitris Lagos)
AI_001	NLIM algorithm within UC1.2 shall be able to identify for a load time series, the individual loads and propose a category/type for each of them	AI non-intrusive load monitoring algorithms as a low-cost technology	The scope of the work	This is the basic feature of NILM	a time series of multiple loads are provided	4		ETRA (Lucas Pons)

AI_002	NILM algorithm within UC1.2 shall be able to label the individual loads identified according to the EU energy labelling criteria for appliances	AI non-intrusive load monitoring algorithms as a low-cost technology	The scope of the product	Energy labelling is a simple way of presenting the appliances energy efficiency that can be used to compare different models/brands and assesss the correctnes of the official labels	Each appliace is in each house if labelled with th appropriate energy efficiency label	3		ETRA (Lucas Pons)
AI_003	UC1.2 shall feature a graphical user interface for the house owner to check the results of NILM and the eco-labelling	AI non-intrusive load monitoring algorithms as a low-cost technology	Look and feel require ments	GUI is mandayory for the users to accept the installation of devices and the participation in the project	GUI is provided	3		ETRA (Lucas Pons)
AI_004	UC1.2 GUI shall let users introduce the details of the applicances they have in its houses	AI non-intrusive load monitoring algorithms as a low-cost technology	Operati onal require ments	In order to properly label the appliances, a minimal information is needed		2		ETRA (Lucas Pons)
AI_005	Availability of measurements (I,V,Q,P) with high sampling rate. CHnnge	AI non-intrusive load monitoring algorithms as a low-	The scope of the product	High sampling rate increases the accuracy of the algorithm	Ideal 1 Hz, maximum1 min	5	Measurements for Current, Voltage, Active & Reactive Power. Temperature measument in low	ICCS (Aris Dimeas)

		cost technology					sampling rage. eg 10-15min	
AI_007	NILM algorithm within UC1.2 should work with 1h granularity data	AI non-intrusive load monitoring algorithms as a low-cost technology	Functional and data requirements			4		EYPESA (Sara Vieira)
AI_008	Detection of unwanted or unexpected islands for PV panels within UC4.3 should be able to detect the blown fuses in the LV grid without the necessity of installing sensors	AI non-intrusive load monitoring algorithms as a low-cost technology	The scope of the product			5		IMPULSA (Lluís Canaves Navarro)
AI_009	To receive the energy consumption data from the smart meters periodically.	AI non-intrusive load monitoring algorithms as a low-cost technology	Functional and data requirements			5		ETRA (Álvaro Nofuentes)
AI_010	The module shall detect abnormal behaviour in the energy assets.	AI non-intrusive load monitoring algorithms	The scope of the product			4		ETRA (Álvaro Nofuentes)

		as a low-cost technology						
AI_011	The module shall estimate a dynamic energy efficiency label of the energy assets.	AI non-intrusive load monitoring algorithms as a low-cost technology	The scope of the product			2		ETRA (Álvaro Nofuentes)
AI_012	In order to train the models, the system needs to have datasets with (at least) 1 year consumption data from different types of energy assets	AI non-intrusive load monitoring algorithms as a low-cost technology	The scope of the work			5	Data coming from the Pilot Sites are specially relevant. Data from public datasets may also be used.	ETRA (Álvaro Nofuentes)
AI_013	The module shal connect via API to HEMS/BEMS from different vendors (like AMIBIT or HIVE)	AI non-intrusive load monitoring algorithms as a low-cost technology	The scope of the product			3		ETRA (Álvaro Nofuentes)
ARC_001	UC1.7 Architecture to operate flexibility markets in the Swiss pilot	Architecture	Operational requirements	An ICT system has to be provided in order to operate the flexibility markets of the Swiss pilot. The system location must be	The ICT system is provided	3	Link to FADP: https://www.kmu.admin.ch/kmu/en/home/facts-and-trends/digitization/data-protection/new-federal-act-on-data-protection-nfadp.html	SUPSI (Davide Strepparava)

				compliant with the Swiss Federal Act on Data Protection (FADP).				
FMD_001	Flexibility market under UC1.7, audits must be carried out to identify controllable assets that are compatible with DR techniques.	Flexibility market design and managemen t	Mandat ed constrai nts	Need to identify assets capable of providing flexibility services and to identify additional devices (e.g. meters) needed for monitoring and controling.	Perform the activity and provide a clear list of assets within the pilot site analysis.	3		AEM (Federico Giani)
FMD_010	The platform through which the end-user will interact with the flexibility market allows the end-user to decide whether they receive a request for flexibility activation, if it happens automatically, or to schedule when to have the different formats.	Flexibility market design and managemen t	Usabilit y and humanit y require ments			3		EYPESA (Sara Vieira)

GNR_004	Historical and forecasting weather data from weather apps	General	Functional and data requirements			3		HYP (Giorgos Pitsiladis)
GPM_001	Availability of historical measurements for total demand and RES production	Grid Planning Methodologies	The scope of the product	Historical Data are necessary to estimate evolution of demand	At least 5 years of historical data with hourly granularity	5		ICCS (Aris Dimeas)
GPM_002	The algorithm for UC4.5 (Improving the grid infrastructure) should help determining if and which investment is needed, when there are new requests for accessing the grid, known issues, or for the yearly investments plan.	Grid Planning Methodologies	The scope of the work			4		EYPESA (Sara Vieira)
GPM_003	The algorithm within UC4.5 should help in planning if and which investment to make on the grid, when there are new requests for accessing the grid, known issues or for the yearly ordinary planning.	Grid Planning Methodologies	The scope of the product			4		EYPESA (Sara Vieira)
GPM_004	The algorithm within UC4.5 (Improve grid	Grid Planning	The scope			4		EYPESA (Sara Vieira)

	infrastructure) should help in planning if and which investment to make on the grid, when there are new requests for accessing the grid, known issues or for the yearly ordinary planning.	Methodologies	of the product					
GPM_005	The algorithm within UC4.5 (Improve grid infrastructure) should simulate different scenarios and compare and prioritise the different options.	Grid Planning Methodologies	The scope of the product			3		EYPESA (Sara Vieira)
HBF_001	UC3.1 and UC 3.2: Definition of input data (e.g. historical data, weather data) for implementation of the forecast	HEMS and BEMS Flexibility and DR optimization	Functional and data requirements			5		SETUP (Klemen Peter Kosovinc)
HBF_002	UC 3.1 and UC 3.2: Definition of output data of the forecast algorithm in order for data to be ready for optimal selection of flexibility	HEMS and BEMS Flexibility and DR optimization	Functional and data requirements			5		SETUP (Klemen Peter Kosovinc)
HBF_003	UC 3.1 and UC 3.2: Evaluate the output of forecast algorithm on the real measurement data	HEMS and BEMS Flexibility and DR optimization	The scope of the product			5		SETUP (Klemen Peter Kosovinc)

HBF_004	UC 3.1: Define different EV charger types and implement forecast for each of the categories	HEMS and BEMS Flexibility and DR optimization	The scope of the product			5		SETUP (Klemen Peter Kosovinc)
HBF_006	UC 3.3: Definition of the time interval of the input (1min/5min/Xmin) in order for output values to be useful for optimal selection of flexibility..	HEMS and BEMS Flexibility and DR optimization	Functio nal and data require ments			5		SETUP (Klemen Peter Kosovinc)
HBF_007	UC 3.1 and UC 3.2: Define the optimal coding language for forecasting algorithm. (it should be integratable with Amibit/Avantcar/sET up platforms)	HEMS and BEMS Flexibility and DR optimization	The scope of the product			5		SETUP (Klemen Peter Kosovinc)
HBF_010	Interface of the BEMS/HEMS flexibility framework with the NILM algorithms component to acquire time series of disaggregated data regarding loads utilized as flexibility assets	HEMS and BEMS Flexibility and DR optimization	The scope of the work			5		HYP (Giorgos Pitsiladis)
HBF_011	HVACs, DHWs, EVs & PVs with storage should compose the	HEMS and BEMS Flexibility	The scope of the product			4		HYP (Giorgos Pitsiladis)

	main household flexibility assets	and DR optimization						
HBF_012	API Integration of the BEMS/HEMS flexibility services with the NODES market platform and aggregators to deliver flexibility forecasts at the prosumer/asset level for flexibility trading	HEMS and BEMS Flexibility and DR optimization	The scope of the work			4		HYP (Giorgos Pitsiladis)
HBF_013	Ensure end-users' comfort boundaries should be considered during flexibility forecasting and not violated during flexibility dispatching	HEMS and BEMS Flexibility and DR optimization	Operati onal require ments			4		HYP (Giorgos Pitsiladis)
HBF_014	BEMS/HEMS integration with the existing infrastructure inside the pilot sites	HEMS and BEMS Flexibility and DR optimization	The scope of the work			3		HYP (Giorgos Pitsiladis)
HBF_015	Remote controllability of the flexibility assets through local IoT controllers or/and smart appliances	HEMS and BEMS Flexibility and DR optimization	The scope of the product			5		HYP (Giorgos Pitsiladis)
HBF_016	Initiliaze algorithms settings according to end-usersâ€™ inputs on desired flexibility assets, comfort preferences, and daily schedules	HEMS and BEMS Flexibility and DR optimization	The scope of the work			4		HYP (Giorgos Pitsiladis)

HBF_017	BEMS/HEMS flexibility services should define dedicated DR campaigns accordind to end-users constraints and degree of involvement	HEMS and BEMS Flexibility and DR optimization	The scope of the product			5		HYP (Giorgos Pitsiladis)
HBF_018	Design/implement various modelling approaches for training asset-specific power consumption profiles and the building spaces thermal behaviour	HEMS and BEMS Flexibility and DR optimization	The scope of the work			4		HYP (Giorgos Pitsiladis)
HBF_019	Desing/develop BEMS/HEMS flexibility and DR services in a modular approach to easily adapt and fit with each pilot site's flexibility asset specifications	HEMS and BEMS Flexibility and DR optimization	The scope of the work			4		HYP (Giorgos Pitsiladis)
HBF_020	BEMS/HEMS flexibility and DR services should rely on an optimization framework constrainted by end-users requirements	HEMS and BEMS Flexibility and DR optimization	The scope of the work			4		HYP (Giorgos Pitsiladis)
HBF_021	Comfort based flexibility profiles should be exploited	HEMS and BEMS Flexibility	The scope			4		HYP (Giorgos Pitsiladis)

	towards the implementation of automated DR strategies.	and DR optimization	of the work					
HBF_022	End-users should be able to bypass any control action generated by the system	HEMS and BEMS Flexibility and DR optimization	Usability and humanity requirements			3		HYP (Giorgos Pitsiladis)
HBF_023	Shifting/shedding of the energy consumption for demand flexibility extraction according to different optimization criteria (i.e. flexibility maximization, comfort maximization, etc) should be available.	HEMS and BEMS Flexibility and DR optimization	The scope of the work			4		HYP (Giorgos Pitsiladis)
HBF_024	UC 3.2: Define different HEMS user types and implement forecast for each of the categories	HEMS and BEMS Flexibility and DR optimization	The scope of the product			5		SETUP (Klemen Peter Kosovinc)
HBF_025	Close to real time energy related metering data including total power & energy consumption data, PV power generation data, EV and battery storage power charging/discharging	HEMS and BEMS Flexibility and DR optimization	Functional and data requirements			5		HYP (Giorgos Pitsiladis)

	data ideally in a 15min or lower granularity							
HBF_026	Close to real time indoor conditions' sensing data including indoor temperature, humidity and occupancy detection (if possible) ideally in a 15min or lower granularity	HEMS and BEMS Flexibility and DR optimization	Functional and data requirements			4		HYP (Giorgos Pitsiladis)
HBF_027	End-users be able to declare desired flexibility assets and their (un)-availability at specific periods	HEMS and BEMS Flexibility and DR optimization	Functional and data requirements			3		HYP (Giorgos Pitsiladis)
IIE_001	When real-time measurements from SCADA systems/smart meters are requested, the the data shall be pre-processed	Integration of DSO and TSO ICT infrastructures into energy management systems	Functional and data requirements	DSO/TSO coordination and data exchange between OPENTUNITY tools and services	EMS/DMS will be provided	4		HEDNO (Vasileios Boglou)
IPM_001	Swiss Pilot site - Real-time data is accessible via Rest API through the FLEXO data management platform	Interoperability with other platforms and management of their historical data	Functional and data requirements	FLEXO requirement	Third-party credentials will be provided to the project's technical partners together with a guideline document.	3	All end-users data will be shared in aggregated and anonymous form.	AEM (Federico Giani)

LCR_001	LCR algorithm within UC1.4 shall be able to identify hot points in a line that could generate a bottleneck of congestion.	Low-cost real-time thermal rating	Operational requirements			5		IMPULSA (Lluís Canaves Navarro)
LCR_002	Availability of temperature measurements with high sampling rate in the line under test for validation purposes.	Low-cost real-time thermal rating	Performance requirements	Actual Temperature data on different locations on the line are required for the validation of Low-cost real-time thermal rating.	Ideal 1 minute of resolution.	5		ICCS (Dimitris Lagos)
LCR_003	The Low-cost real-time thermal rating (LCR) within UC 5.1 should be able to predict possible congestions in the distribution grid	Low-cost real-time thermal rating	Functional and data requirements	This is important to allow the congestion management system within UC 5.1 to prevent congestions and overvoltages		3		AEM (Federico Giani)
LCR_004	Historical Data for algorithm training	Low-cost real-time thermal rating	Functional and data requirements	Historical Data of Current measurements	Granularity of data is at least 1 hour for a period of at least two years.	5	Historical Data for Machine Learning Algorithm trianing and assessment.	ICCS (Dimitris Lagos)

LCR_005	Static Data of line under test	Low-cost real-time thermal rating	Functional and data requirements	Provide the static data of the line under test to conduct indirect calculation of thermal rating	Provision of static data described in comments related to the line and the poles.	5	The data required are: Conductor data (product name, cross section, resistance at 20 Celcius, maximum temperature, existing current rating) Geodata of the overhead line (latitude/longitude of poles)	ICCS (Dimitris Lagos)
LCR_006	Real Time Conductor Current for calculation of RTTR	Low-cost real-time thermal rating	Functional and data requirements	Real time current measurements are required to compute the existing temperature	Granularity of data of at least 1 hour.	5		ICCS (Dimitris Lagos)
LCR_007	For the non-intrusive and cheap measurement of the temperatures in the cables, portatil thermal cameras will be used	Low-cost real-time thermal rating	Costs	Cable temperatures are required to validate the algorithm	temperatures are measured and stored	3		ETRA (Lucas Pons)
OSF_001	UC3.3 we will utilize AMIBITâ€™s Reduxi HEMS systems, which will be connected to SETUP aggregation platforms.	Optimal selection of available flexibility	The scope of the work	Connection will continuously monitor the devices' availability.	Data are exchanged between the AMIBIT's Reduxi HEMS and SETUP	5		AMIBIT (Tomaz Buh)

					aggregation platforms.			
OSF_002	UC3.3. The tool will continuously monitor the devices' availability and adjust the selection accordingly DR units.	Optimal selection of available flexibility	The scope of the product	An algorithm, which will continuously monitor the availability of small-scale devices and adjust the selection accordingly, ensuring that the HEMS is always utilizing the most efficient demand response units.	Optimal DR units will be selected which will have the less impact on the end user comfort, and the highest value of DR potential within household where HEMS is installed.	4		AMIBIT (Tomaz Buh)
OSF_003	Connection between Avantcar charging points/Amibit Reduxi units and Kolektor sETup must be established.	Optimal selection of available flexibility	The scope of the work	Connection is necessary for further interactions.	Stable connection is established	5		UL (Janez Gregor Golja)
OSF_004	UC 3.3: Define the input data (amount of flex, price) for the optimal selection algorithm	Optimal selection of available flexibility	Functional and data requirements			5		SETUP (Klemen Peter Kosovinc)
OSF_005	UC 3.3: Evaluate, if a "security factor" has to be introduced (can algorithm really take into account 10 kW from forecast	Optimal selection of available flexibility	The scope of the product			5		SETUP (Klemen Peter Kosovinc)

	algorithm or should it take into account x % of 10 kW and be on the safe side)							
OSF_006	UC 3.3: Take into account redistribution (or other measures), if one of the assetes will not be able to provide the given/needed flex.	Optimal selection of available flexibility	The scope of the product			5		SETUP (Klemen Peter Kosovinc)
OSF_012	UC 3.3: Define the optimal coding language for the optimal selection algorithm. (it should be integratable with sETup platforms)	Optimal selection of available flexibility	The scope of the product			5		SETUP (Klemen Peter Kosovinc)
OSF_013	UC 3.1, UC 3.2 The forecast algorithm has to provide accurate forecast of consumption and potential flexibility	Optimal selection of available flexibility	Functional and data requirements	Accurate forecast is crucial for optimal selection of flexibility	The needed accuracy of the forecast algorithm is achieved	5		UL (Janez Gregor Golja)
OSF_014	UC 3.2 It would be beneficial if user comfort would be taken into account with the HEMS forecasting algorithm.	Optimal selection of available flexibility	Functional and data requirements	Household unit activation should not have a negative impact on the end-users.	Resident's comfort levels are not impacted.	3		UL (Janez Gregor Golja)
OSF_015	UC 3.1 and 3.2 Historical data is available for accurate forecast modelling.	Optimal selection of available flexibility	Functional and data requirements	Historical data is required for accurate modelling.	Historical data is provided.	5		UL (Janez Gregor Golja)

PPR_001	UC1.10: Each flexibility device must have a QR code for being able to register in the blockchain	Plug and play recognition for flexibility devices	The scope of the work	This is a necessary condition for the automated recognition of each device	Each flexibility device will have a QR marking	4		BSA (Symeon Parcharidis)
PPR_002	UC1.10: All the necessary technical information of the flexibility devices must be stored in the database	Plug and play recognition for flexibility devices	The scope of the work	The technical information of the flexibility devices will be used with in the Opentunity ecosystem	The database must contain all the necessary information for the flexibility devices	4		BSA (Symeon Parcharidis)
PPR_004	For the HVAC systems, the minimum parameters to be included in the QR code should be the type (e.g. room specific, central),the energy source (e.g. electric, gas), the availability (i.e. heating/cooling), the intervention space (e.g. livining room)	Plug and play recognition for flexibility devices	Functio nal and data require ments			4		HYP (Giorgos Pitsiladis)
PPR_005	For the DHW systems, the minimum parameters to be included in the QR code should be the type (e.g. dhw with tank, electric demand heater, electric/gas boiler,	Plug and play recognition for flexibility devices	Functio nal and data require ments			3		HYP (Giorgos Pitsiladis)

	dhw heat pump) and the control method (i.e.relay, plugged)							
TML_001	Knowing the voltage and power of some buses in the grid, the system shall be able to determine the voltages in the rest of the buses of the grid.	Topology identification and state estimation via machine learning	The scope of the product	It is required to have a full observability of the grid.	The status of the buses of all network are known	4		ETRA (Álvaro Nofuentes)
TML_002	Topology detection algorithm within UC4.1 should detect any discrepancy or error and send an alarm when it happens.	Topology identification and state estimation via machine learning	The scope of the product			4		EYPESA (Sara Vieira)
TML_003	Topology detection algorithm within UC4.1 should detect the connection of the different devices to the different phases	Topology identification and state estimation via machine learning	The scope of the product			3	In Anell, we do not know to what phase are connected the devices (such as Smart Meters)	IMPULSA (Lluís Canaves Navarro)
TML_004	Detection of critical points in a electrical line within UC4.4 should be able to automatically establish capacity thresholds vinculated to PV or EV inclusion in different parts of the grid.	Topology identification and state estimation via machine learning	The scope of the product			4	By saying thresholds I mean to set a limit of capacity over which the line o parts of the line can suffer risk of congestions if in the near future a PV installation or an EV suply is connected, due to change of sections in cables.	IMPULSA (Lluís Canaves Navarro)
TML_005	In order to train the models, the system	Topology identification	The scope			5		ETRA (Álvaro Nofuentes)

	needs to have datasets with historical data from V ,I, P, Q	and state estimation via machine learning	of the work					
TML_006	The module shall be receiving periodic data from DSO's SCADA, concentrators and meters.	Topology identification and state estimation via machine learning	Functional and data requirements			5	Other data sources may be also interesting.	ETRA (Álvaro Nofuentes)
TML_007	Topology identification in UC 1.6 shall determine the connections among buses, loads and generators based on the measurements	Topology identification and state estimation via machine learning	The purpose of the product	To be able to define the topology in a semi-automatic way		4		ETRA (Lucas Pons)
TML_008	Topology identification in UC 1.6 shall have access to historical measurements on P,Q, I & V at the relevant points of the grid	Topology identification and state estimation via machine learning	Functional and data requirements	Data is needed to build the model and determine relations		4		ETRA (Lucas Pons)

11.4 ANNEX IV: LIST OF KPIs

KPI ID	KPI_01_Variability of the voltage
KPI Name	Variability of the voltage.
Strategic Objective(s)	SO1. Decarbonization of EU society SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Topology identification and state estimation via machine learning
Related Use Case	UC 1.1 Short-term analysis of the impact of DER in the Distribution grid
Responsible	ETRA
KPI Description	The variation of the supply voltage is defined as an increase or a decrease in the amplitude of the voltage, with respect to its nominal value, which can be caused by variations in input power, variations in loads (e.g. starting of motors, maneuvers in the system) or from system failures.
KPI Formula	$\%Reg_{(down)} = \frac{V_{(no-load)} - V_{(full-load)}}{V_{(no-load)}} \ x\ 100\%$ $\%Reg_{(up)} = \frac{V_{(no-load)} - V_{(full-load)}}{V_{(full-load)}} \ x\ 100\%$
Variables explanation	$V_{(no-load)}$: No-load terminal voltage. $V_{(full-load)}$: Terminal voltage drop when application of a resistive load.
Unit of measurement	Percentage (%)
Baseline	±7%
Target / Thresholds	±5%

	Description	Responsible
STEP 1	Gather historical electrical grid information about voltage in the lines affected by voltage variations.	Pilots
STEP 2	Calculate $\%Reg_{(down)}$ and $\%Reg_{(up)}$ and compare with baseline.	ETRA

KPI ID	KPI_02_NILM F1
KPI Name	F1 score of NILM model
Strategic Objective(s)	SO1. Decarbonization of EU society SO2. Citizen and stakeholder empowerment
Related OPENTUNITY innovation	AI non-intrusive load monitoring algorithms as a low-cost technology for sensorless prosumers.
Related Use Case	UC 1.2 Application of NILM for consumer's energy awareness
Responsible	ETRA
KPI Description	The F1 score is a metric commonly used in the field of machine learning and classification tasks, including Non-Intrusive Load Monitoring (NILM). In the context of NILM, the F1 score assesses the model's ability to correctly identify when a specific device is turned on or off within a household. Specifically, the F1 score is the harmonic mean of precision and recall. Precision measures the proportion of true positive predictions (i.e., instances where the model correctly identifies a device activation) out of all positive predictions (true positives plus false positives). Recall, on the other hand, calculates the proportion of true positives out of all actual positive instances (true positives plus false negatives). In the context of NILM, precision would represent the accuracy of the model in correctly identifying device activations, while recall would indicate the model's ability to capture all actual device activations without missing any. The F1 score strikes a balance between precision and recall, providing a single metric that considers both false positives and false negatives. This is particularly useful in situations where false positives and false negatives have different costs or implications. For example, in NILM, a false positive might result in unnecessary alerts or actions, while a false negative could lead to the failure to detect an important device activation. Therefore, a higher F1 score indicates a more accurate and reliable model for NILM applications.
KPI Formula	$Precision = \frac{TP}{TP + FP}$ $Recall = \frac{TP}{TP + FN}$ $F1 = \frac{2\ x\ Precision\ x\ Recall}{Precision + Recall}$
Variables explanation	TP: True Positives FP: False Positives FN: False Negatives.
Unit of measurement	Percentage (%)
Baseline	0%

Target / Thresholds	60%

	Description	Responsible
STEP 1	Gather historical consumption data of a household including target variable, the individual power of each device to know when each device has been switched on or off.	Pilots
STEP 2	Split the dataset into training and testing sets. Train a prediction model using the collected historical data (train dataset) and test the prediction model using the testing set.	ETRA
STEP 3	Classify every turn on/off of each device into TP, TN, FP and FN by comparing predictions with test dataset.	ETRA
STEP 4	Calculate Precision, Recall and F1 score with TP, TN, FP and FN from last step.	ETRA

KPI ID	KPI_03_Topology Identification MAPE
KPI Name	Mean Absolute Percentage Error (MAE) of State Estimation model.
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Topology identification and state estimation via machine learning
Related Use Case	UC 1.3 Utilization of deep learning for state estimation
Responsible	ETRA
KPI Description	In the context of State Estimation, Mean Absolute Percentage Error (MAPE) is a metric used to evaluate the accuracy of the system state estimation. It quantifies the average absolute difference between the estimated state variables (such as voltage magnitude and phase) and the true values obtained from reliable measurements. Specifically, MAPE provides a measure of how well the estimated state aligns with the actual state of the system, taking into account potential measurement losses or errors. In this scenario, MAPE is computed by taking the absolute difference between the estimated and actual state variables for each network bus then divided by actual state, summing these absolute differences, and then

	dividing by the total number of buses. This yields the average absolute discrepancy, expressed in percentage. A lower MAPE value indicates a more accurate state estimation, implying that the estimated state closely matches the actual state of the system. Conversely, a higher MAPE suggests that there is a greater level of discrepancy between the estimated and actual states, which may be indicative of larger measurement errors or losses.
KPI Formula	$MAE = \frac{1}{n}\sum_{i=1}^{n}\frac{\lvert y_i - \hat{y}_i\rvert}{\lvert y_i\rvert}$
Variables explanation	n is the total number of observations (in this case, the number of network buses). y_i represents de actual state value an bus i. $\hat{y}_i$ represents the estimated state value at bus i.
Unit of measurement	Percentage
Baseline	10%
Target / Thresholds	90%

	Description	Responsible
STEP 1	Gather historical electrical information on all the network buses, in particular, the target magnitudes, voltage and phase.	Pilots
STEP 2	Split the dataset into training and testing sets. Train a prediction model using the collected historical data (train dataset) and test the prediction model using the testing set.	ETRA
STEP 3	Calculate MAPE with the difference between predictions and test label.	ETRA

KPI ID	KPI_04_Capacity_Increase_By_DLR
KPI Name	Average Capacity Increase by Dynamic Line Rating
Strategic Objective(s)	SO1. Decarbonization of EU society SO3. Ensure quality of supply in a context of increase of RES

Related OPENTUNITY innovation	Low-cost real-time thermal rating
Related Use Case	UC 1.4 Real-Time Thermal Rating (RTTR) for capacity calculation of MV lines
Responsible	ICCS
KPI Description	This indicator will measure the average increase in the capacity of overhead lines, in terms of power, due to the deployment of dynamic line rating instead of static thermal rating.
KPI Formula	$\Delta P_{av}^{max} = \sqrt{3}\, V_{nom} \frac{\sum_{i=1}^{N} I_{max,\ dynamic} - I_{max,\ static}}{N}$
Variables explanation	$I_{max,\ dynamic}$: Average Dynamic Line rating since innovation deployment in kA. $I_{max,\ static}$: Static Line rating used by system operator in kA. V_{nom}: Nominal Voltage of Line in kV N: number of samples
Unit of measurement	MW
Baseline	0
Target / Thresholds	5MW

	Description	**Responsible**
STEP 1	Provide static line rating - $I_{max,\ static}$	Pilot site leader (HEDNO, ANELL)
STEP 2	Collect all dynamic ratings computed after deployment of innovation	ICCS
STEP 3	Compute $I_{max,\ dynamic}$ and KPI	ICCS

KPI ID	KPI_05_Maximum_Line_Temperature_Underestimation
KPI Name	Maximum Line Temperature Underestimation
Strategic Objective(s)	SO1. Decarbonization of EU society SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Low-cost real-time thermal rating
Related Use Case	UC 1.4 Real-Time Thermal Rating (RTTR) for capacity calculation of MV lines

Responsible	ICCS
KPI Description	This indicator will measure the robustness of the line temperature calculation that is used for the assessment of the dynamic capacity rating, using actual temperature measurements on the lines under test. The scope is to check whether the temperature of the conductor is underestimated.
KPI Formula	$Max\ Temperature\ Underestimation(C^{o}) = \max_{i=1:N}(\lvert T_{measured} - T_{\text{estimated}} \rvert) I_i$
Variables explanation	$T_{\text{estimated}}$: Conductor temperature estimated by Dynamic Line Rating in C° $T_{measured}$: Conductor temperature measured in the pilot site. N: Total number of measurements I_i: 0 if the temperature is overestimated, 1 if underestimated
Unit of measurement	C°
Baseline	C°
Target / Thresholds	max < 5 C°

	Description	**Responsible**
STEP 1	Provide measurements on conductor temperature, with their respective timestamps on the conductor(s) under test in the pilot.	Pilot site leader (HEDNO, ANELL)
STEP 2	Collect all temperature estimations computed by the innovation for the same testing period.	ICCS
STEP 3	Compute KPI	ICCS

KPI ID	KPI_06_ Accuracy_on_Asset_Condition
KPI Name	Accuracy on Asset Condition
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Advanced asset management.
Related Use Case	UC 1.5 Advanced Asset Management
Responsible	ICCS

KPI Description	This indicator will measure the accuracy of the classification of the pilots' assets to different condition states, using historical data on equipement provided by the DSO.
KPI Formula	$Accuracy = 100\frac{\sum_{i=1}^{N} I}{N}$
Variables explanation	I: *equals to 1 if for asset i the prediction condition category equals to the actual category provided by the DSO* *N: Number of samples*
Unit of measurement	%
Baseline	0
Target / Thresholds	80 %

	Description	Responsible
STEP 1	Provide data related to the calculation of asset management condition.	Pilot site leader (HEDNO, ANELL, IPTO, EL)
STEP 2	Estimate condition state	ICCS
STEP 3	Compute KPI	ICCS

KPI ID	KPI_07_Topology Identification F1
KPI Name	F1 score of Topology Identification model.
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Topology identification and state estimation via machine learning.
Related Use Case	UC 1.6 Topology identification
Responsible	ETRA
KPI Description	The F1 score is a metric commonly used in the field of machine learning and classification tasks, including Topology Identification. In this context, the F1 score it assesses the accuracy of identifying correctly both connections and impedances of the line infrastructure. Specifically, the F1 score is the harmonic mean of precision and recall. Precision measures the proportion of true positive predictions (i.e., instances where the model correctly identifies a line connection) out of all positive predictions (true positives plus false positives). Recall, on the other hand, calculates the proportion of true positives out of all actual positive instances (true positives plus false negatives).

	The F1 score strikes a balance between precision and recall, providing a single metric that considers both false positives and false negatives. This is particularly useful in situations where false positives and false negatives have different costs or implications.
KPI Formula	$$Precision = \frac{TP}{TP + FP}$$ $$Recall = \frac{TP}{TP + FN}$$ $$F1 = \frac{2\ x\ Precision\ x\ Recall}{Precision + Recall}$$
Variables explanation	TP: True Positives FP: False Positives FN: False Negatives.
Unit of measurement	Percentage (%)
Baseline	0%
Target / Thresholds	60%

	Description	Responsible
STEP 1	Gather historical electrical grid data with information about connections and impedances.	Pilots
STEP 2	Split the dataset into training and testing sets. Train a prediction model using the collected historical data (train dataset) and test the prediction model using the testing set.	ETRA
STEP 3	Classify into TP, TN, FP and FN the difference between observed data from the new connections created by the model and the real topology of the network.	ETRA
STEP 4	Calculate Precision, Recall and F1 score with TP, TN, FP and FN from last step.	ETRA

KPI ID	KPI_08_ Increase_in_RES_penetration

KPI Name	Increase in RES penetration
Strategic Objective(s)	SO1. Decarbonization of EU society SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Grid planning methodologies.
Related Use Case	UC 1.7 Investment Deferral considering flexibility UC 2.1 Network planning for High RES penetration UC 4.5 Improving the Grid Infrastructure
Responsible	ICCS
KPI Description	This indicator will measure the increase in RES production in % in a planing scenario where the flexibility sources are optimized as well as the network investments, compared to a Business-As-Usual scenario, where the hosting RES penetration and network upgrades are calculated using the existing established methodologies per pilot.
KPI Formula	$\Delta P_{RES} = 100\frac{\mathrm{P}_{\mathrm{RES}_{\mathrm{R\&I}}} - \mathrm{P}_{\mathrm{RES}_{BaU}}}{\mathrm{P}_{\mathrm{RES}_{BaU}}}$
Variables explanation	$\mathrm{P}_{\mathrm{RES}_{\mathrm{R\&I}}}$: *Annual production of renewables estimated in the pilot with optimal scheduling of flexibility and network investements.* $\mathrm{P}_{\mathrm{RES}_{BaU}}$: *Annual production of renewables estimated with existing methodologies applied in each pilot.*
Unit of measurement	%
Baseline	0
Target / Thresholds	**5%**

	Description	Responsible
STEP 1	Provide cost of network upgrade, historical load and RES data, flexibility assets, flexibility costs and existing methodologies for the network upgrades calculation and RES operation and planning.	Pilot site leader (HEDNO,ANELL)
STEP 2	Compute long term load forecasts and optimization network upgrades and of flexibility sources for annual scenarios..	ICCS
STEP 3	Compute annual RES production in business as usual and optimization of netwok	ICCS

	upgrades considering flexibility sources availability.	
STEP 4	Compute KPI	ICCS

KPI ID	KPI_09_ Investment_Deferral
KPI Name	Investment Deferral from optimal use of flexibility
Strategic Objective(s)	SO1. Decarbonization of EU society SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Grid planning methodologies.
Related Use Case	UC 1.7 Investment Deferral considering flexibility
Responsible	ICCS
KPI Description	This indicator will estimate how the installation and use of local flexibility can affect the deferral of investments in the distribution network considering Business-As-Usual methodologies for network upgrades implemented in the pilot sites, based on long term load and RES production forecasts.
KPI Formula	$\Delta T = \mathrm{T}_{\mathrm{R\&I}} - \mathrm{T}_{\mathrm{base}}$
Variables explanation	$\mathrm{T}_{\mathrm{base}}$: Time of investment in years, in the Business as Usual scenario. $\mathrm{T}_{\mathrm{R\&I}}$: Time of investment in years, when flexibility is installed and optimized.
Unit of measurement	Years
Baseline	0
Target / Thresholds	2

	Description	**Responsible**
STEP 1	Provide cost of network upgrade, historical load and RES data, flexibility assets, flexibility costs, and business as ususal methodology on network upgrades.	Pilot site leader (HEDNO, ANELL)
STEP 2	Compute long term load forecasts and optimization of flexibility sources for annual scenarios.	ICCS

STEP 3	Compute estimated time of investment with and without flexibility optimization	ICCS

KPI ID	KPI_10_Demand Forecasting Accuracy
KPI Name	Demand Forecasting Accuracy
Strategic Objective(s)	SO2. Citizen and stakeholder empowerment
Related OPENTUNITY innovation	HEMS and BEMS Flexibility and DR optimization including initial settings algorithms
Related Use Case	UC 1.8 HEMS/BEMS DR optimization and local flexibility management UC 1.9 Initialization of HEMS/BEMS Demand Response strategy
Responsible	HYP
KPI Description	The mean absolute error (over a given time period) between the actual and the forecasted demand (baseline).
KPI Formula	$MAE_{forecast} = \frac{\sum_{t=1}^{T} \lvert P_{act,t} - P_{b,t} \rvert}{T}$
Variables explanation	$MAE_{forecast}$: mean absolute error between the actual and the forecasted demand (baseline), over a given time period $P_{act,t}$: actual power consumption for a prosumer at time t $P_{b,t}$: baseline (forecasted) power consumption for a prosumer at time t t: time index ($t \in 1, \dots, T$)
Unit of measurement	kW
Baseline	Actual power consumption profile
Target / Thresholds	Short-term: <10%, Mid-term: <30%

	Description	Responsible
STEP 1	Data made available to HYP by pilot partners	HYP, Pilot Sites
STEP 2	Forecasting and comparison with collected data	HYP
STEP 3	Calculation based on the above formula	HYP

KPI ID	KPI_11_Flexibility Delivery Precision
KPI Name	Flexibility Delivery Precision
Strategic Objective(s)	SO2. Citizen and stakeholder empowerment
Related OPENTUNITY innovation	HEMS and BEMS Flexibility and DR optimization including initial settings algorithms
Related Use Case	UC 1.8 HEMS/BEMS DR optimization and local flexibility management UC 1.10 Establishment of a flexibility market and flexibility procurement
Responsible	HYP
KPI Description	This KPI measures the extent to which the flexibility has been delivered according to the initial bid that had been made by the prosumer
KPI Formula	$FD_{error} = \frac{\sum_{t=1}^{T} \lvert P_{del,t} - P_{bid,t} \rvert \cdot I_t}{\sum_{t=1}^{T} P_{bid,t}} \cdot 100\%$
Variables explanation	FD_{error}: percentage error which expresses the degree of under-delivery of flexibility that has been bidded to the flexibility market. $FD_{error} = 100\%$ when $P_{del,t} = 0$ at all time steps. $P_{del,t}$: flexibility delivered at time t $P_{bid,t}$: flexibility bidded at time t I_t: indicator variable which shows if delivered flexibility was enough or not, at time t. If $P_{del,t} < P_{bid,t}$, then $I_t = 1$, indicating underperformance, otherwise $I_t = 0$. t: time index ($t \in 1, \dots, T$)
Unit of measurement	%
Baseline	Bid
Target / Thresholds	0%

	Description	Responsible
STEP 1	Data made available to HYP by pilot partners	HYP, Pilot Sites
STEP 2	Flexibility estimation	HYP
STEP 3	Delivery/Dispatch	HYP
STEP 4	Calculation based on the above formula	HYP

KPI ID	KPI_12_Flexibility Potential
KPI Name	Flexibility Potential
Strategic Objective(s)	SO2. Citizen and stakeholder empowerment
Related OPENTUNITY innovation	HEMS and BEMS Flexibility and DR optimization including initial settings algorithms
Related Use Case	UC 1.8 HEMS/BEMS DR optimization and local flexibility management UC 1.9 Initialization of HEMS/BEMS Demand Response strategy
Responsible	HYP
KPI Description	The amount of energy (for a given time period) that can be provided (given a specific baseline profile for a prosumer) by reducing or temporally deferring demand.
KPI Formula	$$E_{flex} = \sum_{t=1}^{T} (P_{b,t} - P_{opt,t})$$
Variables explanation	E_{flex}: total amount of energy that can be provided by a prosumer to the market operator for a given time period $P_{b,t}$: baseline power consumption for a prosumer at time t $P_{opt,t}$: optimized power consumption for a prosumer at time t t: time index ($t \in 1, \ldots, T$)
Unit of measurement	kWh
Baseline	Baseline profile given
Target / Thresholds	TBD

	Description	Responsible
STEP 1	Data made available to HYP by pilot partners	HYP, Pilot Sites
STEP 2	Baseline estimation	HYP
STEP 3	Flexibility optimization	HYP
STEP 4	Calculation based on the above formula	HYP

KPI ID	KPI_13_GHG Reduction
KPI Name	GHG Reduction

Strategic Objective(s)	SO2. Citizen and stakeholder empowerment
Related OPENTUNITY innovation	HEMS and BEMS Flexibility and DR optimization including initial settings algorithms
Related Use Case	UC 1.8 HEMS/BEMS DR optimization and local flexibility management UC 1.9 Initialization of HEMS/BEMS Demand Response strategy
Responsible	HYP
KPI Description	Reduction in GHG emissions which stems from DR
KPI Formula	$$GHG_{Reduction} = EF \cdot \sum_{t=1}^{T} (P_{act,t} - P_{DR,t})$$
Variables explanation	$GHG_{Reduction}$: GHG reduction which results from DR (only for demand reduction case) EF: emission factor (275 gCO_2eq/kWh) $P_{act,t}$: actual power consumption for a prosumer at time t $P_{DR,t}$: adjusted power consumption for a prosumer at time t t: time index ($t \in 1, \dots, T$)
Unit of measurement	gCO_2eq
Baseline	GHG emissions for actual prosumer demand profile
Target / Thresholds	TBD

	Description	**Responsible**
STEP 1	Data made available to HYP by pilot partners	HYP, Pilot Sites
STEP 2	DR demonstration with focus on delivery of downward flexibility	HYP
STEP 3	Calculation based on the above formula	HYP

KPI ID	KPI_14_Load Reduction/Increase
KPI Name	Load Reduction/Increase
Strategic Objective(s)	SO2. Citizen and stakeholder empowerment

Related OPENTUNITY innovation	HEMS and BEMS Flexibility and DR optimization including initial settings algorithms
Related Use Case	UC 1.8 HEMS/BEMS DR optimization and local flexibility management UC 1.9 Initialization of HEMS/BEMS Demand Response strategy
Responsible	HYP
KPI Description	The amount of energy decrease/increase (due to DR) compared to the actual demand of a prosumer for a given time period. In case of demand reduction, this expresses the energy savings.
KPI Formula	$$E_{change} = \sum_{t=1}^{T} (P_{act,t} - P_{DR,t})$$
Variables explanation	E_{change}: total energy change compared to actual demand of a prosumer. $P_{act,t}$: actual power consumption for a prosumer at time *t*. $P_{DR,t}$: controlled/adjusted power consumption for a prosumer at time *t*. *t*: time index ($t \in 1, \ldots, T$)
Unit of measurement	kWh
Baseline	Actual demand profile of a prosumer
Target / Thresholds	TBD

	Description	Responsible
STEP 1	Data made available to HYP by pilot partners	HYP, Pilot Sites
STEP 2	Flexibility request	HYP
STEP 3	Flexibility dispatch	HYP
STEP 4	Calculation based on the above formula	HYP

KPI ID	KPI_15_Rate of Successful DR Events
KPI Name	Rate of Successful DR Events
Strategic Objective(s)	SO2. Citizen and stakeholder empowerment
Related OPENTUNITY innovation	HEMS and BEMS Flexibility and DR optimization including initial settings algorithms
Related Use Case	UC 1.8 HEMS/BEMS DR optimization and local flexibility management

	UC 1.9 Initialization of HEMS/BEMS Demand Response strategy
Responsible	HYP
KPI Description	The rate of successful DR events compared to the number of total DR requests.
KPI Formula	$R_{S,DR} = \frac{N_{S,DR}}{N_{total,DR}} \cdot 100\%$
Variables explanation	$R_{S,DR}$: rate of successful DR events (percentage) $N_{S,DR}$: number of successful DR events $N_{total,DR}$: number of total DR requests
Unit of measurement	Percentage (%)
Baseline	/
Target / Thresholds	>85%

	Description	**Responsible**
STEP 1	Data made available to HYP by pilot partners	HYP, Pilot Sites
STEP 2	Flexibility request	HYP
STEP 3	Flexibility dispatch	HYP
STEP 4	Calculation based on the above formula	HYP

KPI ID	KPI_16_Thermal Comfort Preservation
KPI Name	Thermal Comfort Preservation
Strategic Objective(s)	SO2. Citizen and stakeholder empowerment
Related OPENTUNITY innovation	HEMS and BEMS Flexibility and DR optimization including initial settings algorithms
Related Use Case	UC 1.9 Initialization of HEMS/BEMS Demand Response strategy
Responsible	HYP
KPI Description	This KPI measures the extent to which temperature is beyond its associated limits (i.e., provides information by how much and for how long the temperature has been outside the predefined boundaries).

	Note: Due to the fact that comfort can be subjective, we might evaluate user comfort using a questionnaire.
KPI Formula	$$TC = \sum_{t=1}^{T} \lvert \theta_{actual,t} - \theta_{limit,t} \rvert \cdot I_t \cdot \Delta t$$
Variables explanation	TC: total amount (sum of products) of degrees that temperature was outside the corresponding limits multiplied by the corresponding duration $\theta_{actual,t}$: actual temperature at time t $\theta_{limit,t}$: temperature limit at time t I_t: indicator variable which shows the existence of a temperature limit violation at time t (can be either zero or one). 0: within limits. 1: outside limits. t: time index ($t \in 1, \dots, T$)
Unit of measurement	˚C·h
Baseline	/
Target / Thresholds	< 1 ˚C·h (this means that temperature is allowed to be outside its predefined limits by one degree and for one hour, or an equivalent)

	Description	Responsible
STEP 1	Data made available to HYP by pilot partners	HYP, Pilot Sites
STEP 2	Identify comfort boundaries	HYP
STEP 3	Demonstration of DR with thermal comfort constraints	HYP
STEP 4	Calculation based on the above formula	HYP

KPI ID	KPI_17_Local Average Voltage Deviation Index
KPI Name	Average Voltage Deviation Index
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Topology identification and state estimation via machine learning. Flexibility market design and management.
Related Use Case	UC 1.10 Establishment of a flexibility market and flexibility procurement

Responsible	#Pilot
KPI Description	The proposed metric is designed to evaluate the effectiveness of the participation of the energy system's operators to a local energy flexibility market. This will be achieved, by introducing an indicator for the voltages on the system's buses.
KPI Formula	The Average Voltage Deviation Index (AVDI) measures the average deviation of voltage levels from the desired or nominal voltage within the distribution network The AVDI indicator is calculated by using the following formula: $$AVDI = \frac{1}{N}\sum_{i=1}^{N}\lvert V_i - V_{nominal}\rvert$$
Variables explanation	$\#V\ [pu]_i$: defines the measured voltage at bus i. $\#V_{nominal}\ [pu]$: defines the nominal voltage level and #n is the number of the buses of the local energy system.
Unit of measurement	pu
Baseline	AVDI>=0.05 pu
Target / Thresholds	AVDI<0.05 pu

	Description	Responsible
STEP 1	Historical data on energy production and consumption within the energy distribution networks will be collected.	#Pilot
STEP 2	Power flow studies, based on real data scenarios, will be conducted, including the deployment of the local energy flexibility market, to estimate AVDI before its establishment.	#Pilot
STEP 3	The operator will participate in the NODES flexibility market platform to submit bids based on the outputs of its bidding system. So, after the participation of the DSO and FSPs at the flexibility market new data will be collected and evaluated.	#Pilot
STEP 4	Power flow studies will be conducted after the	#Pilot

	deployment of the local energy flexibility market to calculate the AVDI and evaluate its effectiveness for the local operators.	

KPI ID	KPI_18_Cost Reduction due to Deferral of Grid Upgrade
KPI Name	Cost Reduction due to the Deferral of BaU Grid Upgrade
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	10. Grid planning methodologies.
Related Use Case	UC 1.7 Investment Deferral considering flexibility
Responsible	# Pilot
KPI Description	The proposed KPI will calculate the cost reduction due to the deferral in the System Operator investments to replace or upgrade the network, by using Business as Usual (BaU) procedures, such as building new transmission lines. This KPI can help to assess the potential benefits of utilizing local flexibility markets to save money and reduce the environmental impact from the construction of new transmission lines.
KPI Formula	$Cost\_reduction = \frac{Cost_{BAU} - Cost_{Flexibilty}}{Cost_{BAU}} * 100\%$
Variables explanation	Cost_reduction: The avoided cost for not upgrading the power grid due to utilization of the local flexibility market. $Cost_{BAU}$: The cost of Business as Usual (BaU) scenario. $Cost_{Flexibility}$: The cost of the proposed local flexibility market scenario.
Unit of measurement	%
Baseline	0
Target / Thresholds	10%
Other comments	This KPI can be calculated by real measurements gathered by the DSO.

	Description	**Responsible**
STEP 1	Determine from the Ten-Year Network Development (TYND) plan the power grid investments that have been	# Pilot

	decided to be made in the general area of Mesogeia.	
STEP 2	Through market assessment and historical data from the operation of the local flexibity market an estimation of the benefits of the market will be conducted. It will be determined which of those investments can be avoided because of the operation of the local energy market.l	# Pilot
STEP 3	By using the formula provided before, the net cost reduction associated with using local flexibility market will be calculated in order to defer investments.	# Pilot
STEP 4	The calculated net cost reduction will be compared with the target value that is set for this KPI in order to draw the appropriate conclusions.	# Pilot

KPI ID	KPI_19_Distribution Network Line Congestion
KPI Name	Distribution Network Line Congestion
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Flexibility market design and management. Low-cost real-time thermal rating.
Related Use Case	UC 1.4 Real-Time Thermal Rating (RTTR) for capacity calculation of MV lines UC 1.10 Establishment of a flexibility market and flexibility procurement
Responsible	#Pilot
KPI Description	The Distribution Network Line Congestion (DNLC) indicator expresses the real power flow on the congested line as a percentage of the line power flow limit. Its purpose is to assess the overload of the lines and the strain that is caused.
KPI Formula	$DNLC\ (\%) = \frac{Power\ Flow}{Line\ \ Limit} * 100\% = \frac{-V_i^2 G_{ij} + V_i V_j G_{ij} \cos(\theta_i - \theta_j) + V_i V_j B_{ij}\ sin(\theta_i - \theta_j)}{Line\ Limit} * 100\%$

	The DNLC can be also expressed as a percentage of the initial DNLC (at the current state of the network, $DNLC_{initial}$) indicator related it to the new one (after the implementation of the flexibility market, $DNLC_{new}$), according to the following formula: $\text{DNLCreduction}\ (\%) = \frac{DNLC_{initial} - DNLC_{new}}{DNLC_{initial}} * 100\%.$
Variables explanation	# $Vi, Vj\ [V]$: Voltage magnitude at the i[th] and j[th] bus respectively. # $\theta i, \theta j$ [degrees]: Phase angle at the i[th] and j[th] bus respectively. # $G_{ij}\ [S]$: conductance of the line connected between buses i and j. # $B_{ij}\ [S]$: susceptance of the line connected between buses i and j. # $Line\ Limit\ [W]$: real power flow limit of the line connected between buses i and j.
Unit of measurement	(%)
Baseline	Over 80%
Target / Thresholds	Below 80%
Other comments	For the evaluation of this KPI the current flows on the lines will be compared with the ones after the integration of the flexibility market. Also, some other parameters of the system like power losses (MW) can be evaluated.

	Description	Responsible
STEP 1	Collection of historical data about lines' currents and implementation of power flow analysis to assess the currents on the Hellenic pilot site and calculate the DNLC indicator ($DNLC_{initial}$).	#Pilot
STEP 2	After the implementation of the local flexibilty market, new power flow study will be performed, considering the participation of the DSO as well.	#Pilot
STEP 3	New data since the participation of FSPs and DSO at the NODES flexibility market will be gathered and assessed.	#Pilot

STEP 4	After STEP 3, the new DNLC ($DNLC_{new}$) indicator will be calculated. To evaluate the contribution of the new flexibility market at the distribution network congestion, we can examine the reduction of DNLC ($\mathrm{DNLCreduction}\ (\%)$):	#Pilot

KPI ID	KPI_20_Local Flexibility Market Requirements Coverage
KPI Name	Local Flexibility Market Requirements Coverage
Strategic Objective(s)	SO2. Citizen and stakeholder empowerment SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Flexibility market design and management.
Related Use Case	UC 1.10 Establishment of a flexibility market and flexibility procurement
Responsible	#Pilot
KPI Description	The proposed metric is designed to evaluate the effectiveness of the FSPs in meeting the requirements and demands of the DSO's local requirements. The KPI serves as a parameter for assessing the system's ability to provide flexibility services effectively to support the energy distribution network.
KPI Formula	The metric for the KPI is defined as the "Local Flexibility Market Requirements Coverage (LFMRC)" indicator and measures the the degree to which the local FSPs align with the needs and of the local operators (TSO/DSO). The LFMRC indicator can be calculated by using the following formula: $$LFMRC = \frac{\sum_{t=1}^{T} LFMRC_{actual}(t)}{\sum_{t=1}^{T} LFMRC_{available}(t)} * 100\%$$
Variables explanation	$\#\boldsymbol{LFMRC_{actual}(t)}$ defines the amount of energy that has been provided by the FSPs to the buyers of the local flexibility market for a given time. $\#\boldsymbol{LFMRC_{available}(t)}$ defines the total amount of energy that is potentially available by the FSPs of the local flexibility market for a given time. $\#\boldsymbol{T}$ refers to a specific time horizon, in which the metric will be calculated.
Unit of measurement	kWh
Baseline	0
Target / Thresholds	LFMRC > 20%

	Description	Responsible
STEP 1	The local operator will implement an optimized bidding strategy based on its objectives and requirements. To achieve this, historical data related to energy production/consumption in the pilot site, grid congestion data, and power flow studies will be performed and analyzed. The bidding system will determine both the requested amount of flexibility and the corresponding price for that amount for a specific time-horizon.	#Pilot
STEP 2	The operator will participate in the NODES flexibility market platform to submit bids based on the outputs of the bidding system. So, after the participation of the DSO and FSPs at the flexibility market new data will be collected and evaluated.	#Pilot
STEP 3	For a given set of time horizons, participation results in the local flexibility market will be collected to calculate the KPI. The two critical parameters are the requested energy amounts and the provided energy amounts.	#Pilot
STEP 4	The KPI for a given indicative set of time horizons will be calculated.	#Pilot

KPI ID	KPI_21_Potential offered flexibility
KPI Name	Potential offered flexibility
Strategic Objective(s)	SO2. Citizen and stakeholder empowerment
Related OPENTUNITY innovation	Innovations: INN2, INN6.

	Work packages: WP4. Technologies to boost flexibility in prosumer's environment and WP5. Technologies for grid operators.
Related Use Case	UC 1.10 Establishment of a flexibility market and flexibility procurement UC 2.1 Network planning for High RES penetration
Responsible	#Pilot
KPI Description	The proposed indicator is designed to measure the potential amount of flexibility that all flexible resources can offer through the market operator's platform.
KPI Formula	The metric for the KPI is defined as the "$FLEXpo$" indicator and relates to the total potential flexibility that is available in market operator's platform. This indicator can be calculated by using the following formula: $$Flex_{PO} = \sum_{i=1}^{i} \sum_{t=1}^{T} P\_flex_{PO\,i,t}$$
Variables explanation	#$\mathrm{P\_flex}_{\mathrm{PO}_{\mathrm{i,t}}}$: The amount of power send from the ith flexible resource at time t to offer flexibility for sale. It contains the potential flexibility that is available to market platform (kW). # i : set of flexible resources # T: given time period
Unit of measurement	kW
Baseline	0
Target / Thresholds	$Flex_{PO} > 1\ kW$

	Description	Responsible
STEP 1	The transmission system operator will take into consideration the outcome of the bidding procedure in order to evaluate the amount of the offered flexibility by the FSPs. The bidding system will determine the requested amount of flexibility for a specific time-horizon.	#Pilot
STEP 2	The operator will participate in the NODES flexibility market platform to submit bids based on the outputs of the bidding system. So, after the participation of the network operators (TSO & DSO) and	#Pilot

	FSPs at the flexibility market new data will be collected and evaluated.	
STEP 3	For a given set of time horizons, participation results in the local flexibility market will be collected to calculate the KPI. The two critical parameters are the amounts of energy and power to be provided for flexibility.	#Pilot
STEP 4	The KPI for a given set of flexible resources at an examined time period will be defined and evaluated.	#Pilot

KPI ID	KPI_22_Type of Flexibility Providers
KPI Name	Type of Flexibility Providers
Strategic Objective(s)	SO2. Citizen and stakeholder empowerment
Related OPENTUNITY innovation	Flexibility market design and management.
Related Use Case	UC 1.10 Establishment of a flexibility market and flexibility procurement
Responsible	#Pilot
KPI Description	This indicator reflects how versatile the Greek Demo is in leveraging flexibility from different technologies. The Demo aspires to make use of flexibility from different technologies. If and how different types of technologies can be accessed and utilized during the Demo phase depends on the number of different technologies that are available in the region of the Demo as well as on the general capabilities of the Demo. This KPI is measured as the relation (in %) between the number of different technologies leveraged in the Demo and the number of types of technologies initially targeted by the Demo. The following technologies will be considered for the KPI calculation: • Renewables • Conventional generators connected to the DS • Conventional generators connected to the TS • Aggregators • Consumers • Storage • Gensets • Electrical vehicles

KPI Formula	The metric for the KPI is defined as the "Type of Flexibility Providers (TFP)" indicator and measures the number the different types of available technologies in the region of the Greek Demo will be utilized. The TFP indicator can be calculated by using the following formula: $TFP = \frac{N_{leverage\_technology}}{N_{target\_technology}} * 100\%$
Variables explanation	$\#\boldsymbol{N}_{leverage\_technology}$: number of different types of technologies utilized during the Demo. $\#\boldsymbol{N}_{target\_technology}$: number of different types of technologies available in the region of the Demo.
Unit of measurement	%
Baseline	0
Target / Thresholds	TFP > 12,5%

	Description	Responsible
STEP 1	The transmission system operator will consider which types of flexibility providers are available in the area of interest.	#Pilot
STEP 2	The operator will evaluate which of the available type of the flexibility providers can participate in the NODES flexibility market platform with respect to the requested energy amount at a given time horizon.	#Pilot
STEP 3	For a given set of time horizons, participation results in the local flexibility market will be collected to calculate the KPI.	#Pilot
STEP 4	The KPI for a given indicative set of time horizons will be calculated.	#Pilot

KPI ID	KPI_23_Accuracy_on_assets_flexibility
KPI Name	Accuracy on assets flexibility

Strategic Objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Flexibility market design and management.
Related Use Case	UC 1.10 Establishment of a flexibility market and flexibility procurement
Responsible	FSP/DSO
KPI Description	Accuracy between baseline value and power measurement when there is no dispatch.
KPI Formula	$$RMSE = \sqrt{\frac{1}{n}\sum e_t^2}$$
Variables explanation	• *t* as settlement period. • *n* as number of settlement periods considered. • *e* as the error, difference between the baseline value and the energy/power measurement (when no dispatch).
Unit of measurement	Percentage
Baseline	50%
Target / Thresholds	10%
Other comments	

	Description	Responsible
STEP 1	Collect data regarding baseline of flexibility resources and measures of resources without dispatch.	FSP/DSO
STEP 2	Calculate the RMSE with the inputs provided.	FSP/DSO

KPI ID	KPI_24_Flexibility used for ancillary services and balancing
KPI Name	Flexibility used for ancillary services and balancing
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Flexibility market design and management.
Related Use Case	UC 1.10 Establishment of a flexibility market and flexibility procurement

<table>
<tr><td>Responsible</td><td>FMO/TSO</td></tr>
<tr><td>KPI Description</td><td>Depending on market set-up it is worthwhile to evaluate the required/activated flexibility of each SO through the bids and trades of FSPs</td></tr>
<tr><td>KPI Formula</td><td>$$\frac{F_{FSP\ bid}}{F_{DSO\ request}}$$</td></tr>
<tr><td>Variables explanation</td><td>

$$\frac{F_{FSPbid}}{F_{DSO\ request}}$$

where:

$F_{DSO\ request}$ Amount of flexibility requested by DSO.

F_{FSPbid} Amount of flexibility offered by FSP

<table>
<tr><td colspan="7">KPI DATA COLLECTION</td></tr>
<tr><td>Data</td><td>Data ID</td><td>Methodology for data collection</td><td>Source/Tools/ Instruments for Data collection</td><td>Location of Data collec-tion</td><td>Frequen-cy of data collection</td><td>Data collec-tion respon-sible</td></tr>
<tr><td>Flexibility requested by DSO</td><td>$F_{DSO\ request}$</td><td>Retrieved from market</td><td>Flexibility market platform</td><td>FMO</td><td>15 min</td><td>FMO</td></tr>
<tr><td>Flexibility offered by FSP</td><td>F_{FSPbid}</td><td>Retrieved from market</td><td>Flexibility market platform</td><td>FMO</td><td>15 min</td><td>FMO</td></tr>
</table>

$F_{FSP\ bid}$: Amount of flexibility requested by DSO.

$F_{DSO\ request}$: Amount of flexibility offered by FSP.
</td></tr>
<tr><td>Unit of measuremen t</td><td>Ratio</td></tr>
<tr><td>Baseline</td><td>/</td></tr>
<tr><td>Target / Thresholds</td><td>/</td></tr>
</table>

	Description	Responsible
STEP 1	Collect data regarding amount of flexibility requested by DSO and amount of flexibility offered by FSP.	FMO
STEP 2	Calculate ratio between inputs gathered.	FMO

KPI ID	KPI_25_User satisfaction
KPI Name	User Satisfaction
Strategic Objective(s)	SO2 Citizen and stakeholder empowerment
Related OPENTUNITY innovation	N/A
Related Use Case	TBD (can be measured either for single features or for full solutions)

Responsible	JR
KPI Description	The KPI will repeatedly measure the overall satisfaction (single-item) of users with the provided solutions at the demo sites and track it over time. For further insights, the satisfaction will be modelled as a function of the perception of the technology against the background of priority topics (identified during Task 2.3, reported in D2.2). The necessary information will be collected with an electronic survey with minimum effort to answer.
KPI Formula	User Satisfaction = $\frac{\sum Satisfaction_i}{n}$ Model Function: $Satisfaction_i = \beta_0 + \beta_1 X_{i1} + \ldots + \beta_p X_{ip} + \epsilon_i$
Variables explanation	**Satisfaction**: Self-reported overall satisfaction with the provided solution **User Satisfaction**: Average self-reported overall satisfaction with the provided solution **β_0**: Intercept **β_p**: Regression coefficient of p^{th} independent variable (solution perception detail variables) **X_{ip}**: i^{th} observed value of p^{th} independent variable **ϵ_i**: Error term
Unit of measurement	Range 1-5 (discrete values for survey respondents: 1 = "not at all satisfied"; 2 = "rather not satisfied"; 3 = "neither satisfied nor unsatisfied"; 4 = "rather satisfied"; 5 = "very satisfied")
Baseline	Measurement at t_0
Target / Thresholds	1. (Average) User Satisfaction > 4 at latest measurement (t_n) 2. Δ in (Average) User Satisfaction > 0 between t_0 and t_n
Other comments	Evaluation of this KPI will be twofold: 1) Development over time 2) Model to assess driving factors behind Overall User Satisfaction (as part of push- and pull-factor analysis)

	Description	Responsible
STEP 1	Decide on granularity of satisfaction measurement	WP team (including JR)
STEP 2	Set up feedback survey and provide access for participation	JR + Pilot(s)
STEP 3	Calculate average (overall) User Satisfaction	JR
STEP 4 (Reporting)	Report target/actual and trend	JR
STEP 5 (Analysis)	Model drivers behind User Satisfaction	JR

KPI ID	KPI_26_ Increase_in_RES_hosting_capacity
KPI Name	Increase in RES hosting capacity
Strategic Objective(s)	SO1. Decarbonization of EU society SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Technologies for grid operators. Grid planning methodologies.
Related Use Case	UC 2.1 Network planning for High RES penetration UC 4.5 Improving the Grid Infrastructure
Responsible	ICCS
KPI Description	This indicator will measure how the optimal use of flexibility can increase the RES capacity in the distribution grid compared to a Business-As-Usual scenario, where the hosting capacity can be calculated using the existing established methodologies per pilot.
KPI Formula	$\Delta C_{RES} = 100 \frac{\text{RES}_{\text{capacity}_{\text{R\&I}}} - \text{RES}_{\text{capacity}_{BaU}}}{\text{RES}_{\text{capacity}_{BBaUASE}}}$
Variables explanation	$\text{RES}_{\text{capacity}_{\text{R\&I}}}$: *Penetration of renewables with netwrok planning that do not consider flexibility optimization* $\text{RES}_{\text{capacity}_{BaU}}$: *Penetration of renewables with netwrok planning* a Business-As-Usual scenario.
Unit of measurement	%
Baseline	0
Target / Thresholds	5%

	Description	Responsible
STEP 1	Provide cost of network upgrade, historical load and RES data, flexibility assets, flexibility costs and existing RES hoting capaity calculation method.	Pilot site leader (HEDNO, ANELL)
STEP 2	Compute long term load forecasts and optimization network upgrades and of flexibility sources for annual scenarios..	ICCS
STEP 3	Compute RES capacity in business as usual and optimization of network	ICCS

	upgrades considering flexibility sources availability.	
STEP 4	Compute KPI	ICCS

KPI ID	KPI_27_EV fleet baseline forecast accuracy
KPI Name	EV fleet baseline forecast accuracy
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increased of RES
Related OPENTUNITY innovation	Optimal selection of available flexibility.
Related Use Case	UC 3.1: Baseline and flexibility forecast for EV fleet
Responsible	AVANTCAR, UL, SETUP
KPI Description	The indicator will measure the accuracy of baseline forecast for the EV fleet.
KPI Formula	The forecast accuracy can be measured with several indicators. The first one which will be used is WMAPE (Weighted Mean Absolute Percentage Error). $$WMAPE = \left(\frac{\sum_{t \epsilon T} \lvert A_t - F_t \rvert}{\sum_{t \epsilon T} \lvert A_t \rvert}\right) \times 100\%$$ This will be calculated for a time period which is to be determined (most likely daily or weekly). Only calculating the accuracy in this way could pose a problem, as the forecast needs to be constantly accurate for some degree. To address this, the accuracy should also be calculated for each time interval (15-min) of the full observation duration. This way any outliers (higher value of error) can be diagnosed. $$MAPE_i = \frac{\lvert A_i - F_i \rvert}{A_i} \times 100\%$$
Variables explanation	A_t ... *Actual power value* F_t ... *Forecasted power value* T ... *observed time period* A_i ... *Actual power value for interval i* F_i ... *Forecasted power value for interval i*
Unit of measurement	Percentage (%)
Baseline	/
Target / Thresholds	10%

	Description	Responsible
STEP 1	Calculation of the baseline	AVANTCAR, UL, SETUP
STEP 2	Measurement collection	AVANTCAR, UL, SETUP
STEP 3	Calculation of the KPI	AVANTCAR, UL, SETUP

KPI ID	KPI_28_EV fleet flexibility forecast accuracy
KPI Name	EV fleet flexibility forecast accuracy
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increased of RES
Related OPENTUNITY innovation	Optimal selection of available flexibility.
Related Use Case	UC 3.1: Baseline and flexibility forecast for EV fleet
Responsible	AVANTCAR, UL, SETUP
KPI Description	The indicator will measure the accuracy of flexibility forecast for the EV fleet.
KPI Formula	The forecast accuracy can be measured with several indicators. The first one which will be used is WMAPE (Weighted Mean Absolute Percentage Error). $$WMAPE = \left(\frac{\sum_{t \epsilon T}\lvert A_t - F_t\rvert}{\sum_{t \epsilon T}\lvert A_t\rvert}\right) \times 100\%$$ This will be calculated for a time period which is to be determined (most likely daily or weekly). Only calculating the accuracy in this way could pose a problem, as the forecast needs to be constantly accurate for some degree. To address this, the accuracy should also be calculated for each time interval (15-min) of the full observation duration. This way any outliers (higher value of error) can be diagnosed. $$MAPE_i = \frac{\lvert A_i - F_i\rvert}{A_i} \times 100\%$$
Variables explanation	A_t ... Actual power value F_t ... Forecasted power value T ... observed time period A_i ... Actual power value for interval i F_i ... Forecasted power value for interval i
Unit of measurement	Percentage (%)
Baseline	/

Target / Thresholds	10%

	Description	Responsible
STEP 1	Calculation of the flexibility	AVANTCAR, UL, SETUP
STEP 2	Test real availability	AVANTCAR, UL, SETUP
STEP 3	Calculation of the KPI	AVANTCAR, UL, SETUP

KPI ID	KPI_29_HEMS fleet baseline forecast accuracy
KPI Name	HEMS fleet baseline forecast accuracy
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increased of RES
Related OPENTUNITY innovation	Optimal selection of available flexibility.
Related Use Case	UC 3.2: Baseline and flexibility forecast for HEMS fleet
Responsible	AMIBIT, UL, SETUP
KPI Description	The indicator will measure the accuracy of baseline forecast for the EV fleet.
KPI Formula	The forecast accuracy can be measured with several indicators. The first one which will be used is WMAPE (Weighted Mean Absolute Percentage Error). $$WMAPE = \left(\frac{\sum_{t \epsilon T} \lvert A_t - F_t \rvert}{\sum_{t \epsilon T} \lvert A_t \rvert}\right) \times 100\%$$ This will be calculated for a time period which is to be determined (most likely daily or weekly). Only calculating the accuracy in this way could pose a problem, as the forecast needs to be constantly accurate for some degree. To address this, the accuracy should also be calculated for each time interval (15-min) of the full observation duration. This way any outliers (higher value of error) can be diagnosed. $$MAPE_i = \frac{\lvert A_i - F_i \rvert}{A_i} \times 100\%$$
Variables explanation	A_t ... *Actual power value* F_t ... *Forecasted power value* T ... *observed time period* A_i ... *Actual power value for interval i* F_i ... *Forecasted power value for interval i*

Unit of measurement	Percentage (%)
Baseline	TBD
Target / Thresholds	10%

	Description	Responsible
STEP 1	Calculation of the baseline	AMIBIT, UL, SETUP
STEP 2	Measurement collection	AMIBIT, UL, SETUP
STEP 3	Calculation of the KPI	AMIBIT, UL, SETUP

KPI ID	KPI_30_HEMS fleet flexibility forecast accuracy
KPI Name	HEMS fleet flexibility forecast accuracy
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increased of RES
Related OPENTUNITY innovation	Optimal selection of available flexibility.
Related Use Case	UC 3.2: Baseline and flexibility forecast for HEMS fleet
Responsible	AMIBIT, UL, SETUP
KPI Description	The indicator will measure the accuracy of flexibility forecast for the HEMS fleet.
KPI Formula	The forecast accuracy can be measured with several indicators. The first one which will be used is WMAPE (Weighted Mean Absolute Percentage Error). $$WMAPE = \left(\frac{\sum_{t \epsilon T} \lvert A_t - F_t \rvert}{\sum_{t \epsilon T} \lvert A_t \rvert}\right) \times 100\%$$ This will be calculated for a time period which is to be determined (most likely daily or weekly). Only calculating the accuracy in this way could pose a problem, as the forecast needs to be constantly accurate for some degree. To address this, the accuracy should also be calculated for each time interval (15-min) of the full observation duration. This way any outliers (higher value of error) can be diagnosed. $$MAPE_i = \frac{\lvert A_i - F_i \rvert}{A_i} \times 100\%$$

Variables explanation	A_t ... *Actual power value* F_t ... *Forecasted power value* T ... *observed time period* A_i ... *Actual power value for interval i* F_i ... *Forecasted power value for interval i*
Unit of measurement	Percentage (%)
Baseline	/
Target / Thresholds	10%

	Description	Responsible
STEP 1	Calculation of the flexibility	AMIBIT, UL, SETUP
STEP 2	Test real availability	AMIBIT, UL, SETUP
STEP 3	Calculation of the KPI	AMIBIT, UL, SETUP

KPI ID	KPI_31_Algorithm latency/calculation time
KPI Name	Optimal selection algorithm latency/calculation time
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Optimal selection of available flexibility
Related Use Case	UC 3.3: Optimal selection of available flexibility
Responsible	UL, KOL
KPI Description	Latency measures the time it takes for the optimal selection algorithm to respond to market requests or activate flexibility units. It assesses the algorithm's responsiveness, helping to ensure timely actions in the energy market.
KPI Formula	$L = TS_{Activation} - TS_{Response}$
Variable explanation	**L:** Latency $TS_{Activation}$: Time Stamp of Response or Activation - the time at which your algorithm responds to a market request or activates a flexibility unit. $TS_{Response}$: Time Stamp of Request - the time at which the market request was received by your algorithm.
Unit of measurement	seconds

Baseline	/
Target / Thresholds	30 s

	Description	**Responsible**
STEP 1	Algorithm testing, gather timestamp of algorithm start (simulated market request) and timestamp of algorithm output (response)	UL, SETUP
STEP 2	Calculation of the KPI	UL, SETUP

KPI ID	KPI_32_Bid satisfaction rate
KPI Name	Optimal selection algorithm bid satisfaction rate
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Optimal selection of available flexibility
Related Use Case	UC 3.3: Optimal selection of available flexibility
Responsible	UL, KOL
KPI Description	Market Bid Satisfaction Rate measures the percentage of successfully accepted market (simulated) bids by the optimal selection algorithm. It assesses the algorithm's effectiveness in fulfilling market demand, indicating its ability to efficiently allocate flexibility resources.
KPI Formula	$$S = \frac{N_{successful}}{N_{total}} \times 100\%$$
Variable explanation	**S [%]**: Bid satisfaction rate $N_{successful}$: The total number of market bids that your algorithm successfully satisfied or accepted. N_{total}: The total number of market bids received by your algorithm, including both accepted and rejected bids.
Unit of measurement	%
Baseline	/

Target / Thresholds	100%

KPI ID	KPI_33_Topology detection F1
KPI Name	F1 score of Topology detection model.
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Topology identification and state estimation via machine learning.
Related Use Case	UC 4.1 Topology detection
Responsible	ETRA
KPI Description	The F1 score is a metric commonly used in the field of machine learning and classification tasks, including Topology detection. In this context, the F1 score it assesses the accuracy of identifying correctly energized components within the distribution network. Specifically, the F1 score is the harmonic mean of precision and recall. Precision measures the proportion of true positive predictions (i.e., instances where the model correctly identifies a energized component) out of all positive predictions (true positives plus false positives). Recall, on the other hand, calculates the proportion of true positives out of all actual positive instances (true positives plus false negatives). The F1 score strikes a balance between precision and recall, providing a single metric that considers both false positives and false negatives. This is particularly useful in situations where false positives and false negatives have different costs or implications.
KPI Formula	$Precision = \frac{TP}{TP + FP}$ $Recall = \frac{TP}{TP + FN}$ $F1 = \frac{2\ x\ Precision\ x\ Recall}{Precision + Recall}$
Variables explanation	TP: True Positives FP: False Positives FN: False Negatives.
Unit of measurement	Percentage (%)
Baseline	0%
Target / Thresholds	60%

	Description	Responsible
STEP 1	Gather historical electrical data such as smart meter voltage data and voltage feeder data.	Pilots
STEP 2	Split the dataset into training and testing sets. Train a prediction model using the collected historical data (train dataset) and test the prediction model using the testing set.	ETRA
STEP 3	Classify into TP, TN, FP and FN the difference between observed data from the topology created by the model and the topology assumed by the network operator.	ETRA
STEP 4	Calculate Precision, Recall and F1 score with TP, TN, FP and FN from last step.	ETRA

KPI ID	KPI_34_ Non_Technical_Losses_Detection_Rate
KPI Name	Non Technical Losses Detection Rate
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Advanced asset management.
Related Use Case	UC 4.2 Fraud detection (non-technical losses)
Responsible	ICCS
KPI Description	This indicator will measure the detection rate of non technical losses in a dataset of smart meters acknoledged already by the DSO as fraudulent or not.
KPI Formula	$$DR = 100\frac{TP}{TP + FN}$$
Variables explanation	TP: *Smart meters where electricity theft has occured and correctly classified as fraudulent.* FN *Smart meters where electricity theft has occured and misclassified as normal.*
Unit of measurement	%

Baseline	0
Target / Thresholds	90 %

	Description	Responsible
STEP 1	Provide data on smart meters consumption and classification as normal/fraudulent per timestamp.	Pilot site leader (ANELL)
STEP 2	Estimate classification of meter	ICCS
STEP 3	Compute KPI	ICCS

KPI ID	KPI_35_Fraud detection accuracy
KPI Name	Fraud detection accuracy
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Topology identification and state estimation via machine learning. Advanced asset management.
Related Use Case	UC4.2 Fraud detection (non-technical losses)
Responsible	ANELL
KPI Description	This indicator will assure the accuracy of fraud detection algorithm within UC4.2. is above a certain threshold.
KPI Formula	$$Accuracy = \frac{TP}{TP + FP}$$
Variables explanation	TP – true positives FP – false positives TN – true negatives FN – false negatives
Unit of measurement	None
Baseline	/
Target / Thresholds	0.90

	Description	Responsible
STEP 1	Collecting data on which potential frauds are actually frauds, when investigating the scene	Anell
STEP 2	Perform final calculation	Anell

KPI ID	KPI_36_Fraud location detection error
KPI Name	Fraud location detection error
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Topology identification and state estimation via machine learning. Advanced asset management.
Related Use Case	UC4.2 Fraud detection (non-technical losses)
Responsible	ANELL
KPI Description	Nowadays, the process of detecting potential frauds at Anell's involves manually inspecting large areas. One of the goals from UC4.2 is to determine a more precise location for the potential fraud. This indicator will measure the spatial resolution, by comparing the algorithm's result with the actual fraud location.
KPI Formula	$\Delta L = \lvert L_{real} - L_{predicted} \rvert$
Variables explanation	L real – real fraud location L predicted – fraud location given by the algorithm
Unit of measurement	m
Baseline	500-600 m
Target / Thresholds	100-200 m

	Description	Responsible
STEP 1	Collect fraud locations given by the algorithm during a certain period	Anell
STEP 2	Collect actual fraud locations during inspection from the same period	Anell
STEP 3	Perform final calculation	Anell

KPI ID	KPI_37_Fraud detection Costs-Benefit Ratio
KPI Name	Costs-Benefit Ratio related to Fraud detection or NTL (Non-Technical Losses) model
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Topology identification and state estimation via machine learning. Advanced asset management.
Related Use Case	UC4.2 Fraud detection (non-technical losses)
Responsible	ETRA
KPI Description	Cost-Benefit Ratio (CBR) measures the economic feasibility of deploying an NTL detection model by considering both the costs associated with reparation or inspection costs (False Positives costs) and the benefits achieved from preventing or addressing non-technical losses (True Positives benefits). • Reparation/Inspection Costs: The costs incurred in investigating and addressing non-technical losses once they are identified. This may include labor, equipment, legal, and administrative costs. • Benefits: The monetary value of non-technical losses that are prevented or mitigated as a result of using the model. This can include recovered revenues from reduced energy theft.
KPI Formula	$CBR = \frac{Benefits}{Costs} x100$ $Costs = \sum_{i=0}^{N_{FP}} Inspection\ costs[€]$ $Benefits = \sum_{i=0}^{N_{TP}} \Big(Congestion[€] - (Inspection[€]\ + (Congestion[€] - Inspection[€])(1 - \frac{\Delta t_i}{90}))\Big)$
Variables explanation	N_{TP}: Number of True Positives N_{FP}: Number of False Positives Congestion [€]: Cost related to congestion of the electrical grid. Inspection [€]: Cost related to inspection of specific part of the electrical grid. Δt_i: time in advance that fraud is detected.
Unit of measurement	Percentage (%)
Baseline	0%
Target / Thresholds	200%

	Description	Responsible
STEP 1	Gather historical electrical consumption data with records or reports of known incidents of non-technical losses from different periods of time.	Pilots
STEP 2	Split the dataset into training and testing sets. Train a prediction model using the collected historical data (train dataset) and test the prediction model using the testing set.	ETRA
STEP 3	Classify every theft or non-theft into TP, TN, FP and FN by comparing predictions with test dataset.	ETRA
STEP 4	Calculate Costs, Benefits and CBR with Number of True Positives and Number of False Positives from above step.	ETRA

KPI ID	KPI_38_Fraud detection F1
KPI Name	F1 score of Fraud detection (Non-Technical Losses) model
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Topology identification and state estimation via machine learning. Advanced asset management.
Related Use Case	UC4.2 Fraud detection (non-technical losses)
Responsible	ETRA
KPI Description	The F1 score is a metric commonly used in the field of machine learning and classification tasks, including Non-Techninical Losses (NTL). In the context of NTL, the F1 score assesses the model's ability to correctly identify cases of fraudulent or unauthorized connections to the electrical grid, often associated with energy theft. Specifically, the F1 score is the harmonic mean of precision and recall. Precision measures the proportion of true positive predictions (i.e., instances where the model correctly identifies a fraud) out of all positive predictions (true positives plus false positives). Recall, on the other hand, calculates the proportion of true positives out of all actual positive instances (true positives plus false negatives). In the context of NILM, precision would represent the accuracy of the model in correctly flagging instances of energy theft out of all the cases it predicts as such, while recall assesses the model's ability to capture all actual cases of energy theft without missing any.

	The F1 score strikes a balance between precision and recall, providing a single metric that considers both false positives and false negatives. This is particularly useful in situations where false positives and false negatives have different costs or implications. For example, in NTL, it ensures that the model minimizes both false alarms (flagging non-fraudulent cases as fraud) and misses as few instances of energy theft as possible.
KPI Formula	$Precision = \frac{TP}{TP + FP}$ $Recall = \frac{TP}{TP + FN}$ $F1 = \frac{2\ x\ Precision\ x\ Recall}{Precision + Recall}$
Variables explanation	TP: True Positives FP: False Positives FN: False Negatives.
Unit of measurement	Percentage (%)
Baseline	0%
Target / Thresholds	60%

	Description	Responsible
STEP 1	Gather historical electrical consumption data with records or reports of known incidents of non-technical losses from different periods of time.	Pilots
STEP 2	Split the dataset into training and testing sets. Train a prediction model using the collected historical data (train dataset) and test the prediction model using the testing set.	ETRA
STEP 3	Classify every theft or non-theft into TP, TN, FP and FN by comparing predictions with test dataset.	ETRA
STEP 4	Calculate Precision, Recall and F1 score with TP, TN, FP and FN from last step.	ETRA

KPI ID	KPI_39_Accuracy of island detection

KPI Name	Accuracy of island detection
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Topology identification and state estimation via machine learning.
Related Use Case	UC 4.3 Detection of unwanted or unexpected islands for PV panels
Responsible	ANELL
KPI Description	The indicator will measure the accuracy or the rate of success against false positive detections.
KPI Formula	$$A = \frac{N_{True}}{N_{True} + N_{False}}$$
Variables explanation	A = Accuracy N_{True} =Number of positives detected by the algorithm that are true in the real operation. N_{False} =Number of positives detected by the algorithm that are false in the real operation
Unit of measurement	Dimensionless
Baseline	0,5
Target / Thresholds	0,75

	Description	**Responsible**
STEP 1	Collect data from the different assets in the grid.	ANELL
STEP 2	Collect data from failures in the grid.	ANELL
STEP 3	The algorithm is continiously running and detecting anomalous situations.	Algorithm developer
STEP 4	The algorithm detects a blown fuse and records the incident.	Algorithm developer

KPI ID	KPI_40_Detection of grid islands F1
KPI Name	F1 score of detection of grid islands model.
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increase of RES

Related OPENTUNITY innovation	Topology identification and state estimation via machine learning.
Related Use Case	UC 4.3 Detection of unwanted or unexpected islands for PV panels
Responsible	ETRA
KPI Description	The F1 score is a metric commonly used in the field of machine learning and classification tasks, including detection of grid islands. In this context, the F1 score assesses the model's ability to correctly identify when a specific line protection cuts off the power and creates a grid island. Specifically, the F1 score is the harmonic mean of precision and recall. Precision measures the proportion of true positive predictions (i.e., instances where the model correctly identifies a grid island) out of all positive predictions (true positives plus false positives). Recall, on the other hand, calculates the proportion of true positives out of all actual positive instances (true positives plus false negatives). The F1 score strikes a balance between precision and recall, providing a single metric that considers both false positives and false negatives. This is particularly useful in situations where false positives and false negatives have different costs or implications.
KPI Formula	$Precision = \frac{TP}{TP + FP}$ $Recall = \frac{TP}{TP + FN}$ $F1 = \frac{2\ x\ Precision\ x\ Recall}{Precision + Recall}$
Variables explanation	TP: True Positives FP: False Positives FN: False Negatives.
Unit of measurement	Percentage (%)
Baseline	0%
Target / Thresholds	60%

	Description	Responsible
STEP 1	Gather historical electrical information about line protections and island creations.	Pilots
STEP 2	Split the dataset into training and testing sets. Train a prediction model using the collected historical data (train dataset) and test the prediction model using the testing set.	ETRA

STEP 3	Classify every line protection cut off into TP, TN, FP and FN by comparing predictions with test dataset.	ETRA
STEP 4	Calculate Precision, Recall and F1 score with TP, TN, FP and FN from last step.	ETRA

KPI ID	KPI_41_Detection time
KPI Name	Detection time
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Topology identification and state estimation via machine learning.
Related Use Case	UC 4.3 Detection of unwanted or unexpected islands for PV panels
Responsible	ANELL
KPI Description	The indicator will measure the difference between the algorithm's and the real grid operator's time of detection for a blown fuse.
KPI Formula	$$\Delta t = t_{operative} - t_{algorithm}$$
Variables explanation	Δt = difference of time $t_{operative}$ = time when the blown fuse is detected since it happens in the real operation of ANELL's grid $t_{algorithm}$ = time when the blown fuse is detected since it happens from the algorithm
Unit of measurement	Minutes (min)
Baseline	The result must be positive.
Target / Thresholds	More than 60 min

	Description	**Responsible**
STEP 1	Collect data from the different assets in the grid.	ANELL
STEP 2	Collect data from failures in the grid.	ANELL

STEP 3	The algorithm is continiously running and detecting anomalous situations.	Algorithm developer
STEP 4	The algorithm detects a blown fuse and records the time in which it was detected.	Algorithm developer

KPI ID	KPI_42_Electrical points detection
KPI Name	Detection of critical points in the grid
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Topology identification and state estimation via machine learning.
Related Use Case	UC 4.4 Detection of critical points in a electrical line
Responsible	ETRA
KPI Description	Distribution cables can suffer section changes along the line while supplying different clients. This means that a reduction of the section in certain parts of the grid will suppose a reduction on the capacity of the line and, thus, a potential risk of congestion in those parts of the line with lower section. This KPI is focusing in comparing the increase of congestions due to reduced section compared to the same line assuming there's no changes in section. It will be calculated as a percentage.
KPI Formula	$Congestion\ rise = \frac{Cong_f - Cong_0}{Cong_0} * 100$
Variables explanation	$Cong_f$= maximum possible capacity of congestion calculated from the scenario that considers the changes in section. $Cong_0$= maximum possible capacity of congestion calculated from the scenario that considers that the section is the same for the entire line.
Unit of measurement	Percentage (%)
Baseline	0%
Target / Thresholds	50%

	Description	**Responsible**
STEP 1	Provide information about section changes along the target line to create both scenarios.	#Pilot

STEP 2	Calculate maximum allowed capacity for each scenario running power flows.	ETRA
STEP 3	Calculate congestion rise using the formula and the maximum allowed capacities.	ETRA

KPI ID	KPI_43_ Decrease_in_investment_costs
KPI Name	Decrease in investment costs
Strategic Objective(s)	SO1. Decarbonization of EU society SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Grid planning methodologies.
Related Use Case	UC 4.5 Improving the Grid Infrastructure
Responsible	ICCS
KPI Description	This indicator will measure the investments costs decrease (%) in a planing scenario where the flexibility sources are optimized as well as the network investments, compared to a Business-As-Usual scenario, where the hosting RES penetration and network upgrades are calculated using the existing established methodologies per pilot.
KPI Formula	$$\Delta P_{RES} = 100\frac{C_{BaU} - C_{R\&I}}{C_{BaU}}$$
Variables explanation	C: *Cost of network upgrades estimated in the pilot with optimal scheduling of flexibility and network investements.* C_{BaU}: *Cost of network upgrades estimated with existing methodologies applied in each pilot.*
Unit of measurement	%
Baseline	0
Target / Thresholds	5%

	Description	Responsible
STEP 1	Provide cost of network upgrade, historical load and RES data, flexibility assets, flexibility costs and existing methodologies for the network upgrades calculation and RES operation and planning.	Pilot site leader (ANELL)
STEP 2	Compute long term load forecasts and optimization network upgrades and of flexibility sources for annual scenarios..	ICCS
STEP 3	Compute costs of network upgrades in business as usual and optimization of netwok upgrades considering flexibility sources availability.	ICCS
STEP 4	Compute KPI	ICCS

KPI ID	KPI_44_Average amount of flexibility available from the energy community
KPI Name	Average amount of flexibility available from the energy community
Strategic Objective(s)	SO2. Citizen and stakeholder empowerment SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	HEMS and BEMS Flexibility and DR optimization including initial settings algorithms. Flexibility market design and management.
Related Use Case	UC 5.1 Improve congestion management to facilitate DERs penetration UC 5.2 Integrate flexibility with the distribution grid to provide balancing services
Responsible	AEM
KPI Description	This KPI measures the standard deviation of the flexibility available from the energy community in a specific time interval. With energy management systems (EMSs), it is possible to monitor the flexibility available at the level of individual assets in a specific time interval, thus averaging it across all assets in the community. This flexibility is not a constant value but can change from instant to instant depending on the state of asset utilisation in the community. Through the calculation of the standard deviation, it is therefore possible to gain an insight into the flexibility expected to be available to the aggregator from the energy community.
KPI Formula	$\mu_{flex\ t} = \frac{\sum_n^N P_n}{N}$

	$$\mu_{flex\ mean} = \frac{\sum_t^T \mu_{flex\ t}}{T}$$ $$\sigma_{flex} = \sqrt{\frac{\sum_t^T \left(\mu_{flex\ t} - \mu_{flex\ mean}\right)^2}{T}}$$
Variables explanation	n : single flexibility asset in the energy community. N : total number of flexibility assets in the energy community. t : single time step. T : total number of time steps. P_n : quantity of power in kW available from a single flexibility unit. $\mu_{flex\ t}$: average quantity of power available from the flexibility units within the energy community in the time instant t. $\mu_{flex\ mean}$: average quantity of power available from the flexibility units within the energy community in period T. σ_{flex} : standard deviation to measure the dispersion of averaged data around the mean.
Unit of measurement	kW
Baseline	Direct measure of the amount of flexibility that the EMS communicate to the FPS.
Target / Thresholds	TBD
Other comments	The main objective is to investigate the potential of flexibility within the energy community. The aim is therefore to achieve as small a standard deviation as possible.

	Description	Responsible
STEP 1	Data collection on the flexibility available for the aggregator from the energy community assets for a given period.	HYP
STEP 2	Calculation of indicators	HYP

KPI ID	KPI_45_Average peak load reduction at the MV/LV transformer station
KPI Name	Average peak load reduction at the MV/LV transformer station
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Topology identification and state estimation via machine learning.

Related Use Case	UC 5.1 Improve congestion management to facilitate DERs penetration UC 5.2 Integrate flexibility with the distribution grid to provide balancing services
Responsible	AEM
KPI Description	This KPI evaluates the effectiveness of the peak load reduction strategy on the secondary side of the MV/LV transformer, located upstream of the energy community under investigation. The objective is to verify the effectiveness of the flexibility offered by the energy community in reducing possible congestion at the local transformer substation. The KPI provides three key indicators to assess the impact of asset control, providing information on both the power reduction and the energy required to lower the peak.
KPI Formula	$y_{max} = \max_{t \in \mathcal{T}} y(t)$ $y_{max,ctrl} = \max_{t \in \mathcal{T}} y(t) + y_{flex}(t) = \max_{t} y_{ctrl}(t)$ $\text{KPI}_1 = y_{max} - y_{max,ctrl}$ $\text{KI}_1 = \Delta t \sum_{t=1}^{T} maximum\left(y(t) - y_{max,ctrl}, 0\right)$ $\text{KI}_2 = \text{KI}_1/\text{KPI}_1 \quad \text{if } y_{max} > y_{max,ctrl}$
Variables explanation	t : single time step $\mathcal{T}$: total number of time steps y_{max} : maximum peak of the power profile over the period $y(t)$: power in kW in the time instant t $y_{max,ctrl}$: maximum peak of the power profile over the period after peak shaving control actions $y_{ctrl}(t)$: power in kW in the time instant t after peak shaving control actions KPI_1 : quantity of power in kW reduced by the controller KI_1 : the quantity of energy in kWh needed to reduce the peak KI_2 : the quantity of energy in kWh needed to reduce tot kW
Unit of measurement	KPI_1 : kW KI_1 : kWh KI_2 : kWh/kW
Baseline	TBD
Target / Thresholds	TBD

	Description	**Responsible**
STEP 1	Data collection from the secondary side of the transformer located upstream the energy community, before	AEM

	and after the peak reduction for a given time period T.	
STEP 2	Data reception and calculation of the KPI	ETRA

KPI ID	KPI_46_Error in the prediction of electricity demand
KPI Name	Error in the prediction of electricity demand
Strategic Objective(s)	SO1. Decarbonization of EU society SO2. Citizen and stakeholder empowerment SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	WP4. Technologies to boost flexibility in prosumer's environment. WP5. Technologies for grid operators.
Related Use Case	UC 5.1 Improve congestion management to facilitate DERs penetration UC 5.2 Integrate flexibility with the distribution grid to provide balancing services
Responsible	Topology identification and state estimation via machine learning.
KPI Description	The KPI measures the accuracy and reliability of forecasts of expected energy consumption, considering all delivery points in the energy community. It quantifies the difference between predicted electricity demand and actual electricity use. A lower percentage or error value indicates more accurate forecasts, while a higher error suggests less accurate forecasts.
KPI Formula	$AFE_{demand} = \frac{\sum_i^I RMSE_{forecasted\ demand\ i}}{I}$ $RMSE_{forecatsed\ demand\ i} = \sqrt{\frac{1}{T}\sum_t^T (E\ Actual_t - E\ Forecasted_t)^2}$
Variables explanation	i : single point of delivery I : total number of delivery points t : single time instant T : total number of time steps AFE_{demand} : average demand forecast error $RMSE_{\ forecasted\ demand\ i}$: root mean square error of forecast demand for unit i $E\ Actual_t$: Actual energy in time t $E\ Forecasted_t$: Forecasted energy in time t
Unit of measurement	kWh
Baseline	TBD
Target / Thresholds	TBD

	Description	Responsible
STEP 1	Historical data provision for all the point of delivery in the energy community. A time series for each POD for period T.	AEM
STEP 2	Calculation of the energy demand forecast for each delivery point in period T.	ETRA
STEP 3	Calculation of the KPI	ETRA

KPI ID	KPI_47_ Error in the prediction of photovoltaic production
KPI Name	Error in the prediction of photovoltaic production
Strategic Objective(s)	SO1. Decarbonization of EU society SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	Topology identification and state estimation via machine learning.
Related Use Case	UC 5.1 Improve congestion management to facilitate DERs penetration UC 5.2 Integrate flexibility with the distribution grid to provide balancing services
Responsible	AEM
KPI Description	The KPI measures the accuracy and reliability of forecasts of expected energy production, considering the photovoltaic systems installed in the energy community. It quantifies the difference between predicted energy production and actual production. A lower percentage or error value indicates more accurate forecasts, while a higher error suggests less accurate forecasts.
KPI Formula	$AFE_{production} = \frac{\sum_i^I RMSE_{forecasted\ demand\ i}}{I}$ $RMSE_{forecatsed\ production\ i} = \sqrt{\frac{1}{T}\sum_t^T (E\ Actual_t - E\ Forecasted_t)^2}$
Variables explanation	i : single PV system I : total number of PV systems t : single time instant T : total number of time steps

	$AFE_{production}$: average production forecast error $RMSE_{forecasted\ demand\ i}$: root mean square error of forecast production for unit i $E\ Actual_t$: Actual energy production in time t $E\ Forecasted_t$: Forecasted energy production in time t
Unit of measurement	kWh
Baseline	TBD
Target / Thresholds	Lower the better
Other comments	The main objective is to investigate the potential of flexibility within the energy community. The aim is therefore to achieve as small a standard deviation as possible.

	Description	**Responsible**
STEP 1	Historical data provision for the PV system in the energy community in period T.	AEM
STEP 2	Calculation of the energy production forecast for the PV system in period T.	ETRA
STEP 3	Calculation of the KPI	ETRA

KPI ID	KPI_48_flexibility_activation_accuracy
KPI Name	Flexibility activation accuracy
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	HEMS and BEMS Flexibility and DR optimization including initial settings algorithms.
Related Use Case	UC 5.1 Improve congestion management to facilitate DERs penetration UC 5.2 Integrate flexibility with the distribution grid to provide balancing services
Responsible	SUPSI
KPI Description	Flexibility is usually actuated on the base of a flexibility estimation or forecast. An important KPI is the quantification of how reliably a certain amount of flexibility can be activated.

	To measure reliability of the flexibility estimation, we propose to use the mean relative absolute error between the observed and forecasted power profile of a group of controlled devices, when a control signal is delivered.
KPI Formula	$\frac{1}{\lvert\mathcal{T}\rvert}\sum_{t\in\mathcal{T}}\left\lvert\frac{y(t)-x(t)}{x(t)}\right\rvert$ $\quad\mathcal{T}:\{t:n_{activated}>0\}$
Variables explanation	**y**: observed profile of the flexible devices, during a flexibility call **x**: requested profile of the flexible devices, during a flexibility call **T**: set of timesteps in which the number of activated devices is greater than 0 **n_activated**: number of activated devices **MAE**: mean absolute error over the flexibility call period
Unit of measurement	**y**: kW **x:** kW
Baseline	-
Target / Thresholds	0.3

	Description	Responsible
STEP 1	Before T: Periodical collection of 15-minutes data related to the flexibilities available for the aggregation and to the meteorological situation	AEM, HYP, HIVE
STEP 2	Before T: Performing of flexibility forecast and aggregation for time-slot T	SUPSI
STEP 3	@ T: Activation of flexibility	SUPSI, HYP
STEP 4	After T: Collect data related to the aggregated flexibilities	AEM, HYP, HIVE
STEP 5	After T: Calculation of KPI(T)	SUPSI

KPI ID	KPI_49_Max_flexibility_prediction_accuracy
KPI Name	Max flexibility prediction accuracy
Strategic Objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Related OPENTUNITY innovation	HEMS and BEMS Flexibility and DR optimization including initial settings algorithms.
Related Use Case	UC 5.1 Improve congestion management to facilitate DERs penetration UC 5.2 Integrate flexibility with the distribution grid to provide balancing services
Responsible	SUPSI
KPI Description	Flexibility is usually actuated on the base of a flexibility estimation or forecast. An important KPI is how reliable is the estimation of the maximum flexibility that can be activated. To measure reliability of the flexibility estimation, we propose to use the mean relative absolute error between the observed and forecasted power profile of a group of controlled devices, when a control signal is delivered to all the flexible devices. To retrieve the values of this KPI, one must simultaneously activate all the available flexibilities. Since knowing the maximum available flexibility is crucial to calibrating the system, and to know how much flexibility can be traded in the flexibility market. We expect this procedure to take place sporadically but systematically during operations.
KPI Formula	$\frac{1}{\lvert\mathcal{T}\rvert}\sum_{t\in\mathcal{T}}\left\lvert\frac{y(t)-x(t)}{x(t)}\right\rvert$ $\mathcal{T}:\{t: n_{activated} = n_{max}\}$
Variables explanation	**y**: observed profile of the flexible devices, during a flexibility call **x**: forecasted profile of the flexible devices, during a flexibility call **T**: set of timesteps in which the number of activated devices is greater than 0 **n_activated**: number of activated devices **n_max**: maximum number of devices that can be activated **MAE**: mean absolute error over the flexibility call period
Unit of measurement	**y**: kW **x:** kW
Baseline	-
Target / Thresholds	0.3

	Description	Responsible
STEP 1	Before time slot T:	AEM, HYP, HIVE

	Periodical collection of 15-minutes data related to the flexibilities available for the aggregation and to the meteorological situation	
STEP 2	Before T: Performing of flexibility forecast and aggregation for time-slot T	SUPSI
STEP 3	@ T: Activation of flexibility	SUPSI, HYP
STEP 4	After T: Collect data related to the aggregated flexibilities	AEM, HYP, HIVE
STEP 5	After T: Calculation of KPI(T)	SUPSI