D6.1 Deployment and demonstration plan

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Use case, Test case, Key performance indicator, Demonstration, Dataset, Trust and acceptance.

Executive Summary

This report documents the outcome of the first half of Task 6.1 (Overall coordination of Pilot Sites) within the OPENTUNITY project, which coordinates deployment and demonstration activities across pilot sites in Greece, Switzerland, Spain, and Slovenia. The task brings together pilot leaders and technical partners to define the test cases, datasets, KPIs, and other pilot-specific inputs required for the demonstration activities and future evaluation activities. As first deliverable of WP6 (Deployment and demonstration activities), it establishes a common methodology used simultaneously across all pilots, ensuring a controlled execution of the test cases. The main objective of this deliverable is to report on the methodology chosen to direct testings and the demonstrations plans for each pilot.

The report provides a structured overview of the preparatory work for the demonstration phase. It includes pilot site characterization, the set of use cases to be tested, deployment and demonstration plans, and the associated test cases, datasets, and KPIs.

It offers a detailed description of these elements to ensure a proper setup, thorough assessment, and achievement of targets. Namely, the pilot site characterization contains not only the equipment, partners, and their roles, but also clear user scenarios for interacting with OPENTUNITY innovation tools, along with a feedback collection plan, to guide improvements interactions and demonstration activities. A breakdown of all the steps required for technology deployment and demonstration is also outlined. Test cases are developed in detail and mapped with relevant datasets (both prior to demonstration and those collected during demonstration), with KPIs (Figure 1) that are essential for evaluation (WP7), and with strategic objectives.

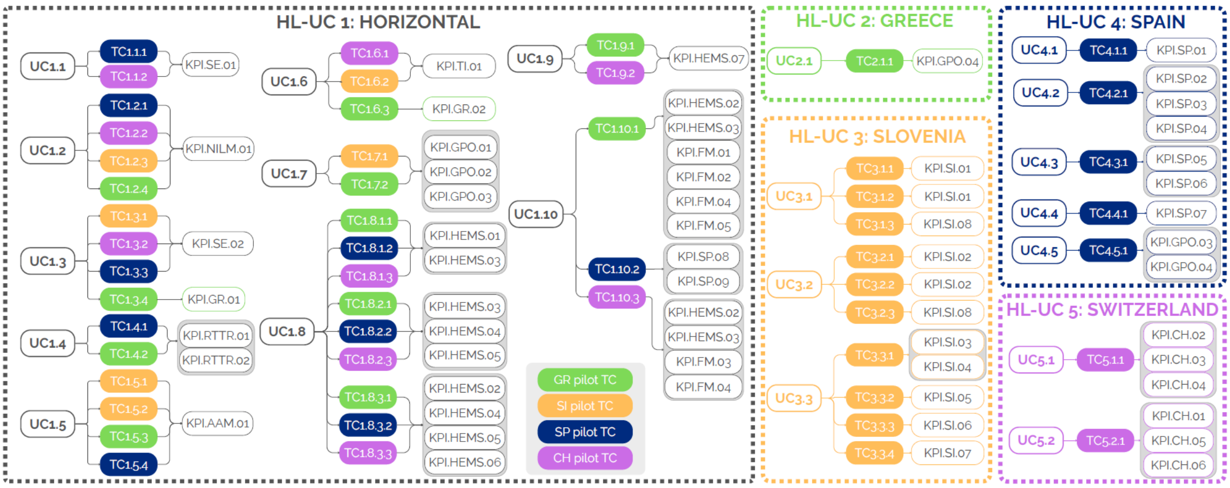

Figure 1. Overview of the OPENTUNITY test cases performed in each pilot and their mapping with KPIs

Finally, pilot-specific risks are identified and complemented with contingency actions to support effective risk management. A common methodology organises all pilot contributions, ensuring that activities are consistently planned, monitored, and assessed across the project. User trust-related aspects are also discussed (Chapter 7).

Some activities have been completed at the time of publication (asset and technical innovation deployment, definition and mapping of test cases, datasets, KPIs, and strategic objectives, and the estimation of KPI baselines) and the rest of activities (test case execution, risk logs) will continue throughout WP6 and T6.1 (M24 – M42). Accordingly, this deliverable serves as an introduction to the demonstration activities and will be complemented with results of the demonstrations in D6.2 in M42.

In line with the recommendations received during the first review meeting, this deliverable also reinforces several key aspects across all pilots:

i. **Project objectives**: Each pilot has clearly outlined its objectives, mapped against the project's three strategic objectives. This mapping directly links the demonstration activities with the KPIs that will be calculated, ensuring that each pilot contributes to the overall validation of the OPENTUNITY approach.

ii. **Baselines**: Baselines have been defined for each KPI on a pilot-specific level. This work was carried out in collaboration with ICCS, leader of Task 7.1 (Techno-environmental impact assessment). While the current definitions represent an initial estimation, further refinement will take place as more pilot data becomes available, allowing for more accurate baseline values.

iii. **Feedback collection**: Each pilot site has developed a comprehensive plan for gathering feedback. This includes mechanisms for collecting input internally (within the pilot and between pilot sites and technical partners) as well as externally (from stakeholders such as companies and citizens). This report details the nature, method, frequency, and purpose of the collected feedback in pilots.

iv. **User scenarios**: Pilot sites identified the scenarios and use cases where successful demonstration depends on user interaction. For each scenario, they defined the expected behaviour, potential deviations, and mitigation strategies to encourage the desired user actions. This ensures that demonstrations are realistic and robust against uncertainties in user participation.

v. **Trust issues**: As part of the citizen engagement activities, a survey was conducted (co-created by Amibit and JR and disseminated through multiple channels to maximize outreach). The survey targeted end users and explored their perspectives on energy consumption, management, costs, and willingness to engage as active energy consumers. Based on the survey results, JR prepared a dedicated section addressing trust issues, both in the context of the OPENTUNITY project and in view of future roll-out. This work will serve as a foundation for continued citizen engagement activities, where building and maintaining trust will remain a central focus.

Copyright statement

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1 Introduction

1.1 Purpose of the document

The objective of this report is twofold. For the most part, D6.1 presents the current outcome of Task 6.1, where pilot sites and technical leaders worked together to prepare the test cases, datasets, KPIs, and pilot-specific inputs needed for the OPENTUNITY demonstrations. Its purpose is to consolidate pilot site deployment and demonstration activities, ensure comparability across pilots, and provide a common framework for WP6. This deliverable also provides an in-depth review of trust and acceptance issues by OPENTUNITY tools users, which is a first step in the topic of stakeholder engagement (which will be tackled more widely in D6.2) and which will be important for Tasks 7.2 (impact assessment) and 7.4 (policy recommendations).

1.2 Scope of the document

The report provides a comprehensive overview of the preparatory work undertaken for the demonstration phase of the OPENTUNITY project. It covers the characterization of each pilot site, the use cases to be demonstrated, the deployment and demonstration timelines, the list of detailed test cases, datasets, and the consolidated KPIs with their mapping. Pilot-specific risks are also identified and addressed with a contingency plan. While each element is presented from a pilot-specific perspective, all follow a common methodology, ensuring that activities are planned, monitored, and assessed consistently and transparently across all pilots.

1.3 Structure of the document

Chapter 2 outlines the general methodology used in Task 6.1 to develop deployment plans, test cases, demonstration activities and risk management plans for the pilots. It also includes all template tables to support the reading of the following chapters. Chapters 3 to 6 present the full set of contributions for each pilot: Greek, Swiss, Spanish, and Slovenian. These include the pilot site characterization, deployment plan, defined test cases, associated datasets and KPIs, demonstration plan, and risk management plan. Chapter 7 provides an in-depth discussion of the monitoring approach and trust-related aspects. Chapter 8 concludes the report while Chapter 10 (Annex) compiles all test cases, datasets and KPIs for the reference.

2 Methodology overview

As part of Task 6.1, pilot sites and innovation developers (technical leaders) worked together to prepare the test cases, datasets, KPIs, and pilot-specific inputs needed for the project demonstrations. Gantt charts and descriptive (text) documents were continually updated during the last 10 months to track progress effectively. These living working documents were refined and their final version is provided in this deliverable, giving individual pilot site contributions for its demonstration planning activities

In summary, the table below provides an overview of the T6.1 activities up until the publication of this report.

Table 2.1. Timeline of Task 6.1 until D6.1 publication

Contributions	2024	2025									
	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
	M24	M25	M26	M27	M28	M29	M30	M31	M32	M33	M34
Deployment plan											
Equipment check											
Pilot site characterization definition											
Test cases definition											
Datasets definition											
Demonstration plan											
Risk log											

The rest of this section outlines the structure followed in the deliverable to describe each pilot's demonstrations.

2.1 Pilot site characterization

Each chapter of this report is focused on a specific pilot site. To give more context to the scope of each pilot site in OPENTUNITY, we present first a concise overview of the pilot's location, main objectives, existing infrastructure, and specific challenges, followed by a more detailed list of roles and responsibilities of the different partners in this pilot, the installed and ongoing deployment of equipment, the data collection plan, and the scenarios made about user interactions with the tools and innovations being tested.

Below is the overview of all the subsections included in each pilot.

Pilot site description

This section provides a high-level introduction to the pilot site, explaining its location, main objectives, existing infrastructure, and unique characteristics and challenges.

Pilot site roles

This section provides an overview of the partners involved in the pilot site, outlining their roles and responsibilities. The goal is to clearly define who is contributing to the pilot and what their main tasks are.

Installed and planned equipment overview

As part of the OPENTUNITY project, various types of equipment (such as measurement and control devices) are being installed or upgraded to enable proper monitoring, control, and testing of innovations. This section provides an overview of the physical infrastructure that is either already installed and operational, planned, or currently being deployed within the pilot site.

For each type of new equipment (to be) installed, a short description, the location in the grid, the installation status, and its purpose are provided in the form of a table.

Feedback collection plan

This section outlines how feedback will be gathered throughout the demonstration activities. Feedback is critical to assess the perceived value, usability, and replicability of OPENTUNITY innovations.

Two types of feedback should be considered:

- End-user and stakeholder feedback: this covers the perceptions, experiences, and engagement of end users and external stakeholders (e.g., DSOs, municipalities, aggregators, consumers).
- Internal partner feedback: this refers to reflections and input from project partners directly involved in the design, implementation, and operation of the demonstrations.

Feedback collection plans are simply presented in a table format (Table 2.2) which details the information collected, stakeholders it relates to, methods of retrieval, frequency of feedback collection, and the direct benefits it brings to OPENTUNITY solutions.

Table 2.2. Template of the feedback collection plan

What will be collected	Who is involved	Methods	Frequency	Use of input
Name of the feedback	e.g. DSO, consumers, firm, technical partner	e.g. survey, interview	When collection started and how often it repeats	How the feedback is used for improvements

User scenarios, assumptions, and impacts

User scenarios have been developed as the expected interaction between end-users and technical innovation tools tested in pilots. They provide a basis for the development of the test cases as they imagine the ideal environment in which use cases can be optimally demonstrated. As shown in Table 2.3, the aim is to identify actors involved in the demonstrations, the general interaction expected between the tools and their users, and the necessary conditions for interaction to be successful (e.g. enough knowledge, access to data, enough staff or time available), but also the risks and potential actions to take if these conditions are not met.

Table 2.3. Template of the user scenario

Innovation/tool	Scenario description	Assumptions made	Expected effect if assumptions not met
What the end-user is interacting with	Expected interaction between the end-user and the tool	Conditions (behaviour, environment, performance) expected to be true for the scenario to work as intended	Potential risks and consequences if conditions are not met

2.2 Deployment plan

The deployment plan provides an overview of all installations and upgrades that are needed to carry out the demonstrations at each pilot site. It ensures that all technical components required for measuring, communicating, and controlling are in place before the official start of the testing.

The deployment plan is presented in the form of a simple Gantt chart, which shows the months during which each activity was performed.

Table 2.4. Template of the deployment plan. The timestamp marked in red represents the actual start of demonstration activities.

Pilot site deployment	2023				2024												2025											
	Jan - Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	M01 - M09	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	M25	M26	M27	M28	M29	M30	M31	M32	M33	M34	M35	M36
Step 1		■	■																									
Step 2				■	■																							
Step 3						■	■	■																				
Step 4						■	■	■	■																			
Step 5								■	■	■	■	■	■	■														
Step 6													■	■	■	■	■											
Step 7																		■	■	■								
Step 8																					■	■	■	■	■			
Step 9																					■	■	■	■	■			
Step 10																								■	■			

These tables have been filled, updated and monitored throughout the first months of Task 6.1 under the coordination of UL.

2.3 Test cases, datasets and KPIs

Test cases

The starting point for defining test cases was the set of use cases (UCs) selected by each pilot and described in deliverable D2.1 – Technical Foundations [1]. Each pilot site reviewed the UCs relevant for its demonstration and then translated them into test cases (TCs). Each test case was thoroughly developed to include all aspects of its execution: (i) partners, assets, datasets, preconditions needed before the implementation, (ii) experimental steps and exception paths, and (iii) output data, KPIs and targets. The ID of test cases is inherited from use case numbering, with the final digit representing the xth test case associated to the same use case.

In a few cases, additional test cases have been linked to separate innovations (data space, plug an play), so independent test cases have also been defined, using the same template. These test cases are included in a separate subsection in Annex 1 (section 10.1.5).

Table 2.5 presents the template used for all test cases.

Table 2.5. Template of a test case

Test case ID	**In the form of TCX.X.X (e.g. TC1.1.1)**
Name	Concise, descriptive name for the test case
Timeframe	Expected testing period
Targets	What this test case aims to validate. It needs to be measurable
Actors involved	List the actors involved in the test case, specifying their roles
Assets & systems involved	List of assets (e.g. battery, cold storage room) and systems (e.g. SCADA of the DSO) used in the test

Triggering event	Condition, action, or input that initiates the execution of the test case
Pre-condition	List of conditions that must be met before the test can start
Test case description	Step-by-step overview of how the test will be conducted, including: • Setup steps (e.g., data preparation, system readiness) • Execution steps (e.g., running the forecast, activating flexibility) • Post-execution steps (e.g., data collection, results analysis)
Exception path(s)	List of alternative steps to perform the test case in the event of foreseeable problems
Post-condition	Expected state after the experiment concludes
Datasets required	Input datasets needed to conduct the test
Output data	Datasets collected during the test, needed for evaluation
Related KPIs	KPIs which will monitor and evaluate this test case; this ensures the test is linked to project performance metrics
Related pilot	Pilot site where the test will be conducted
Results of the experiment	
Reserved for documenting the quantitative results after the test is performed.	
Qualitative analysis of the results	
Reserved for documenting observations, lessons learned, and non-quantitative insights after the test (e.g., challenges encountered, system behaviour under stress, suggestions for improvement).	

These test case tables have been built up during the first months of Task 6.1 and the last two fields (results, quantitative analysis) will be reported in the next deliverable D6.2, which will be published at the end of the demonstration phase (M42).

The tables are fully detailed in the Annex of this document, while in the core of the report, we kept the most descriptive information, i.e. test case objectives, involved partners, involved assets, and the testing environment (live/simulated/hybrid).

Datasets

Dataset characterisation is required for monitoring test cases and demonstration activities. Reliable and detailed datasets ensure that each test case can be executed and validated with the appropriate data.

Table 2.6. Template of a dataset description

Dataset ID	**In the form of DS.Pilot.XX (e.g. DS.GR.01)**
Data element	Descriptive name of the data
Data description	What the data represents, how it is collected (source/system), and its relevance for the demonstration activities
Confidentiality	Public / Confidential
Access	How the data is obtained, including methods and restrictions
Source of data	Device or system generating the data
Measurement units	Unit(s), e.g. kW, %, kV
Resolution	Granularity of data collection
Data reception frequency	How often the data is retrieved or made available for use
Time coverage	Start and end dates, or ongoing coverage window
Data format	Structure or file type of the data (e.g., CSV, JSON)
Related test cases	List of relevant test cases

Datasets were first defined by test case authors and then refined and agreed with pilot sites. All dataset tables are provided in the annex and a mapping of test cases and datasets is provided in the core of the report.

Key Performance Indicators (KPIs)

KPIs are calculated to evaluate the performance of the test cases. An initial set of KPIs was developed in deliverable D2.1, but updates are necessary since the operational site scopes and asset constraints have been refined, analysed and specified. As a result, some KPIs have been kept as they were, some had to be modified to reflect actual testing better, others removed, and new ones have been introduced where relevant.

To avoid inconsistencies, pilot-specific KPIs have been re-indexed with pilot-specific IDs (e.g., “KPI.SI.01”, “KPI.ES.01”) while horizontal KPIs have been re-indexed with simplified IDs (e.g., “KPI_06_Accuracy on asset condition” was renamed “KPI.AAM.01”). For each pilot, this report provides a table mapping current KPIs to those in D2.1.

KPIs are mapped to the relevant test cases, but they are also linked to the strategic objectives defined in the project proposal. A complete description of the KPIs is provided in Annex, following the same template as introduced in D2.1.

KPI baselining

To properly assess project impact (WP7), KPI values measured during and after the demonstrations will be benchmarked against baseline conditions. These baselines represent either the business-as-usual scenarios or the efficiency of the OPENTUNITY tools before testing with pilot site data. KPIs will be calculated at the end of the demonstration phase (as part of Task 7.1, led by ICCS, to evaluate demonstrations impact) and the success of the OPENTUNITY project will be evaluated against each KPI's baseline values. Baseline and target values are summarised in the KPI tables in Annex, while the core report also provides an explanation for each KPI baseline, and if relevant, how the target value was defined.

2.4 Demonstration plan

The main role of the demonstration plan is to connect test cases with practical implementation and KPI measurement. As this report is being published at the end of the development phase of the project and just before the start of the demonstration phase, we set out the demonstration plan in the form of a timeline (Table 2.7) that pilots will follow for the execution of their test cases.

Table 2.7. Template of the demonstration plan The timestamps marked in red represent the start and end of demonstration activities.

Pilot demonstration plan	2025				2026								
	Jan 2023 - Sep 2025	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	M01-M33	M34	M35	M36	M37	M38	M39	M40	M41	M42	M43	M44	M45
Test case													
Step 1													
Step 2													
Step 3													
Step 4													
Step 5													
KPI evaluation and analysis													

This demonstration plan is the basis for the rest of the testing activities and will be reassessed at the end of the project and presented in the final deliverable D6.2.

2.5 Risk management plan

The risk management plan allows each pilot site to anticipate and address potential issues that could affect the demonstrations. The risk list builds on the project-level risks already identified prior to and at the very beginning of the project as reported in deliverable D1.1 – Project Management Plan [2]. The risk list has been adapted to pilot specificities, and it was expanded to risks identified during the first two phases of the project (use cases and project requirement definition, design and development of technical innovations), with the evolution and clarification of use cases and pilot scopes. The refined risks are presented here in the form of a table, classified (technical, data-related, user-related, organizational, or exploitation-related), rated in term of likelihood and impact, and a contingency plan to address them.

Table 2.8. Template of the risk management plan

Risk ID	Risk description	Category	Likelihood	Impact	Mitigation/contingency action
In the form of PI.XX	Short description	Technical / Data-related / User-related / Organizational / Exploitation risk	Low / Medium / High	Low / Medium / High	Planned measures to reduce risk likelihood or impact, or to respond if it occurs. If relevant, name responsible partner.

3 Greek pilot site

3.1 Pilot site characterization

3.1.1 Pilot site description

3.1.1.1 Location – Existing infrastructure

The Greek Demo site is located in Mesogia, a suburb of Athens within Attica region. Mesogia is part of the Greek interconnected system and encompasses the municipalities of Koropi, Lavrio, Nea Makri as well as the interconnected islands of Kea, Andros and Tinos. This semi-rural area serves approximately 225,000 customers across both low voltage (LV) and medium voltage (MV) networks, ranging from residential users to small, medium, and large-scale industries. The area benefits from installations of diverse renewable sources, including large wind farms, and photovoltaic (PV) parks, as well as rooftop PVs.

The pilot installation of the OPENTUNITY project is powered by the Markopoulo HV/MV substation and the downstream connected distribution network (MV feeders). The substation consists of three MV transformers and steps the voltage down, from 150kV to 20kV. The HV/MV substation serves as the interface between the electricity transmission network, managed by Independent Power Transmission Operator (IPTO), and the electricity distribution network, managed by Hellenic Energy Distribution Network Operator (HEDNO).

Smart electronic meters have been deployed for all MV customers and for selected LV customers, distributed across feeders connected to the three transformers of the Markopoulo substation. HEDNO operates an advanced metering infrastructure (AMI) integrated with a meter data management system, which processes, validates, and stores metering data collected at 15-minute intervals. Additionally, automatic meter reading (AMR) retrieves smart meter data via general packet radio service (GPRS) every 24 hours. While all MV customers are equipped with electronic telemetering meters, the majority of LV customers still rely on electromechanical meters, which require manual data logging. Moreover, 100 smart meters have been deployed utilizing an unbundled smart meter architecture, dividing functionalities into a smart metrology meter and a smart meter extension.

Data from the distribution network, sourced from GIS, advanced MV meters, Advanced Metering Infrastructure (AMI), PMUs, SCADA, and the telemetry centre, will support the validation of WP5 tools, including state estimation, topology detection, real-time thermal rating, investment deferral and planning optimization tool. Moreover, transformer operational data from the transmission electricity grid, obtained via ad hoc SCADA and EMS measurements, are utilized to identify malfunctions and prevent transformer failures. These measurements, owned by the Transmission System Operator (TSO), will be utilized for short-term asset management. Finally, the use of smart metrology will support the energy market participation. The data of the smart meters will be used by both system operators to estimate and validate the required amount of flexibility in the critical assets of the substation, hence the selected number of feeders, for the efficient participation in the Local Flexibility Market designed in WP4.

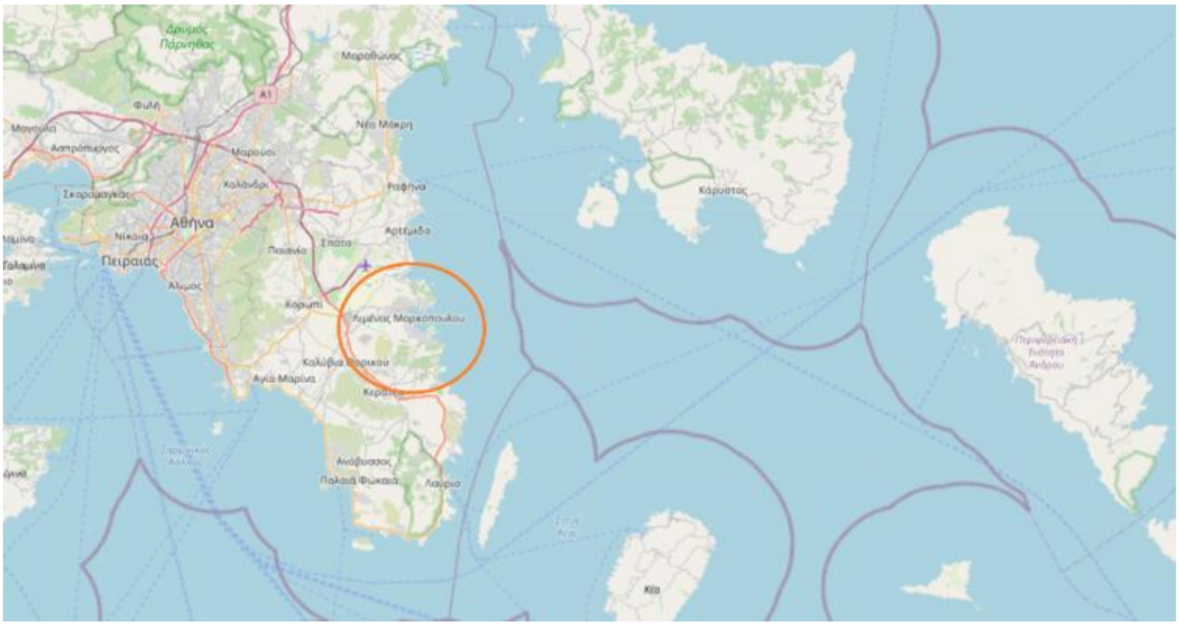


Figure 2 .Location of the Markopoulo substation

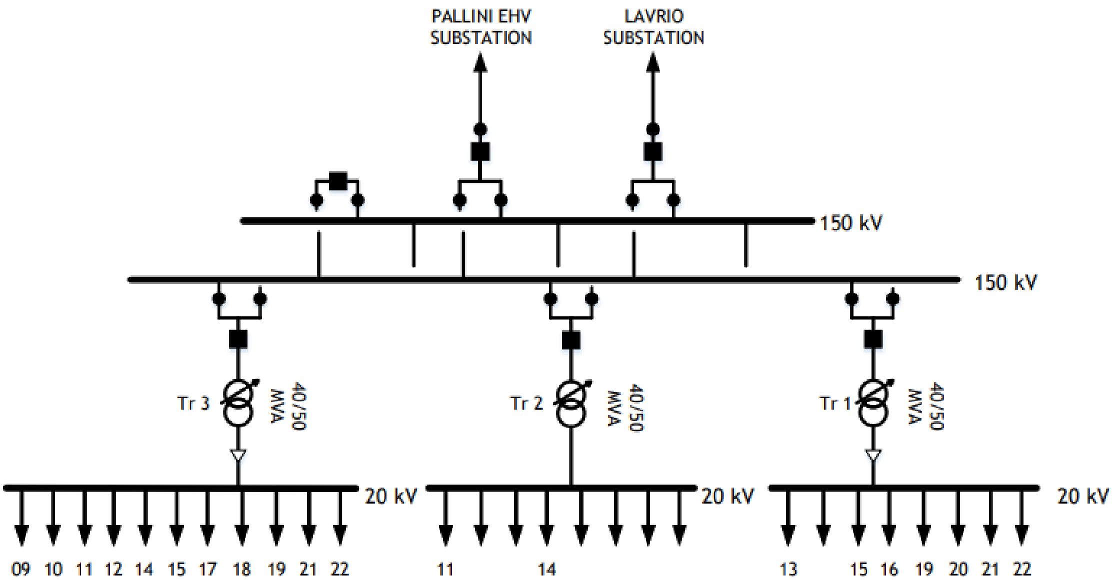


Figure 3. Structure of the Markopoulo HV/MV substation

3.1.1.2 Objectives of the pilot site

The selection of this location as a pilot site was strategically driven by specific challenges and needs aimed at increasing the penetration of RES, particularly through net-metering. This objective is underpinned by three main pillars:

- Efficient network management to address challenges posed by rooftop PV installations,
- Effective utilization of flexibility,
- Implementation of innovative planning techniques for greater RES penetration in the medium term, as the region's solar potential and building stock fully supports it.

Moreover, this area is prone to potential congestion issues that might arise due to increased RES integration, further justifying its selection for the Greek pilot site. In this context, the pilot aims to ensure the stability, reliability, and normal operation of the Greek energy system, while increasing the RES share without compromising the security and smooth operation of the networks. To this end, enhanced network observability, the application of new planning methodologies, and the integration of available flexibility resources are critical components. These efforts will be further supported through the testing of a Local Flexibility Market (LFM), where both IPTO and HEDNO will participate as buyers, enabling the exploration of TSO/DSO coordination via improved data sharing mechanisms in the context of the market. In addition, a local energy community from Attika region (Collective Energy) will engage with the NILM module to identify the different loads of households using just the RT smart meter data as an input.

The aforementioned issues and challenges highlight the relevance of testing and implementing the innovative tools developed in WP5, which are tailored to the evolving needs of system operators. They also reinforce the value of participating in the LFM designed in WP4, where both IPTO and HEDNO will act as buyers of flexibility provided by assets connected to the distribution network.

3.1.2 Pilot site roles

Table 3.1. GR pilot site roles

Partner	Role in the pilot	Main responsibilities
HEDNO	Pilot site leader, DSO	Provides part of the distribution grid for testing WP4, and WP5 innovation and shared grid related data. Buyer of the flexibility services offered in the flexibility market.
IPTO	TSO	Provides part of the transmission grid for testing WP4, and WP5 innovation and shared grid related data. Buyer of the flexibility services offered in the flexibility market.
ICCS	IT provider, FSP	Implementation of the DSO and TSO oriented tools in WP5. Assists HEDNO and IPTO in pilot implementation and innovation development. FSP in the Greek LFM designed in WP4. Offers flexible loads, PV installations of around 3kWp, a battery storage system of 5kWh Li-ion batteries and 20-25 residential customers which are members of Collective Energy (CoEn), an energy community located in Attica region.
HYP	FSP	FSP in the Greek LFM designed in WP4. Manages a portfolio of residential loads, including 48kW power from water heaters, 24kW from air conditioning, PV capacity of 4kW and other plugged loads for testing purposes.
ETRA	IT provider	NILM technical partner

3.1.3 Installed and planned equipment overview

Table 3.2. GR pilot equipment overview

Equipment type	Description	Location	Installation status	Purpose
LV monitoring devices	Devices providing measurements of voltage, current, active/reactive power and power factor (cosφ).	MV/LV substations, MV feeder departing from Markopoulo HV/MV substation	3 existing, 1 planned (by December 2025)	Provide visibility of power flows in MV/LV substations. Data will be used for state estimation, topology identification, and the flexibility market.
PMUs	Phasor measurement units (PMUs) installed at MV/LV substations to measure voltage magnitude and angle, with full synchronization.	MV side of MV/LV substations	3 planned (by December 2025)	Support real-time, PMU-based state estimation and topology identification
Line sensor	Sensor to be installed directly on the line to measure current, vibrations, conductor temperature, and conductor pitch	Overhead MV line	1 planned (by December 2025)	Support the validation and assessment of the Dynamic Real-Time Thermal Rating (DRTTR) tool
Meteorological stations	Weather stations to be installed in the region of the pilot site to measure ambient temperature	1 in MV/LV Markopoulo substation 2 in the adjacent EHV/HV substations (Pallini and Lavrio)	3 planned (by December 2025)	Supply with the weather input data and support the asset management tool

3.1.4 Feedback collection plan

Within the framework of the Greek pilot, two main entities are identified. The first entity consists of end users (consumers), who participate in the local energy flexibility market of the Greek demo, as energy flexibility providers, and are affiliated with one of the two FSPs. The second group consists of the end users of the energy system operators participating in the Greek pilot, who will operate the tools designed for the power transmission and distribution systems.

End-user and stakeholder feedback

In the Greek pilot, end-users consist primarily of residential consumers who participate as flexibility providers in a Local Flexibility Market. These consumers are engaged via two FSPs and respond to flexibility signals/requests sent by the FSPs. Moreover, some of the consumers are actively engaging with the NILM tool. Through their participation, the end-users provide flexibility services to the transmission and distribution system operators (TSO and DSO) of the Greek pilot. Feedback from these participants will be collected to evaluate:

- How readily and effectively flexibility providers respond to market requests, and their satisfaction with the process and
- Perceived incentives for participation (e.g. environmental benefits, smoother grid operation, financial rewards) and any barriers or concerns.

To gather this feedback, the Greek pilot team is designing questionnaires, conducting interviews, and organizing informational workshops with end-users. A mailing list has already been set up for the Greek pilot, allowing interested participants to register and stay informed or volunteer feedback. The table below summarizes the key aspects of end-user and stakeholder feedback collection in the Greek pilot.

Table 3.3. GR pilot end-user feedback collection plan

What will be collected	Who is involved	Methods	Frequency	Use of input
Motivations and barriers for engagement in the LFM	Households participating via FSPs (aggregator's customers) / FSPs	Surveys, interviews, workshops	During pilot trials (e.g. after flexibility events) and post-trial	Improve market design and communication, refine aggregator-user interaction
General feedback on user-facing tool features (e.g. energy usage reports)	NILM users	Surveys, feedback forms	After tool setup and after some weeks of use (periodic checks)	Refine tool design and usability, ensure the provided data is correct

Internal partner feedback

Internal feedback will be collected in two layers, focusing on both operational coordination within the Greek pilot team and alignment with cross-project innovation development:

1. **Among Greek pilot partners:** Regular communication among the Greek pilot's core partners HEDNO (DSO), IPTO (TSO), HYP (FSP) and ICCS (developer of tools for grid operators) that will ensure that data exchange pipelines, system integrations, and demonstration activities run smoothly. These discussions focus on technical and organizational challenges encountered during implementation (for instance, ensuring SCADA, PMU, and telemetry data streams are reliable), monitoring the progress of each use case, and addressing any issues.
2. **Between Greek partners and horizontal innovators:** Feedback channels between the Greek pilot team and the project's horizontal innovation leaders (notably NODES as the Local Flexibility Market Operator, and the OPENTUNITY's grid tools' developers in WP4/WP5) are established to discuss demonstration progress and requirements. This includes sharing the DSO/TSO's perspective on new tools (e.g. advanced asset management, state estimation, grid planning, real-time thermal ratings) and ensuring that the pilot's operational realities are informing the ongoing refinement of these innovations.

Table 3.4. GR pilot internal feedback collection plan

What will be collected	Who is involved	Methods	Frequency	Use of input
Data pipeline reliability (SCADA, PMUs, AMI)	HEDNO, IPTO, ICCS	Weekly technical calls	Weekly, during demo phase	Ensure data robustness, continuous flow, and troubleshoot potential errors

Tool performance and demonstration progress (DSSE, RTTR, advanced asset management, grid planning)	HEDNO, ICCS, IPTO,	Bi-weekly technical calls	Bi-weekly	Refine execution of test cases, monitor KPIs, track milestones and progression
TSO-DSO coordination in integrated flexibility market	HEDNO, IPTO, NODES,	Bilateral meetings	As needed (per activation round or during every testing phase)	Adapt market design, improve coordination mechanisms

3.1.5 User scenario assumptions and impacts

In the Greek pilot, end-users will interact with two main OPENTUNITY innovations: (i) the Local Flexibility Market, participating via the FSP in which they belong and (ii) the NILM tool. Additionally, OPENTUNITY grid tools (e.g. state estimation, topology identification, planning tool) will be evaluated by HEDNO's and IPTO's internal departments. End-user consumers are expected to use the NILM tool to monitor appliance-level consumption and efficiency labels, while those offering flexibility (through FSPs) will allow their assets to be controlled when the DSO/TSO requests flexibility. On the utility side, HEDNO and IPTO staff will interact with new grid operation tools to improve network management. The table below summarises the user scenario assumptions, expected impacts if assumptions are unmet, and engagement activities so far for the Greek pilot.

Table 3.5. GR pilot user scenarios

Innovation/tool	Scenario description	Assumptions made	Expected effect if assumptions not met
TSO-DSO common flexibility market (via FSPs)	End-users participate in the Greek demo local flexibility market through FSPs. They offer flexible capacity which can be activated to help the DSO and TSO. Users are notified of activation events and later informed of their rewards/impact. They also join workshops or surveys about their experience.	Enough end-users enrol through FSPs to provide the required flexibility volume for the pilot.	In cases where a higher flexibility volume is requested, the pilot may apply a scaling approach, whereby the contribution of existing participants is proportionally multiplied to reflect aggregated response.
Grid operation tools (DSO and TSO internal)	HEDNO's grid management departments use new OPENTUNITY tools in their operational planning and control for the pilot area. These tools assist in detecting grid issues, forecasting grid state etc. HEDNO and IPTO staff will integrate these tools into their workflow during the trial.	Staff engagement: HEDNO's and IPTO's engineers and operators actively test each new tool and devote time to use them in their operations during the pilot testing. Feedback loop: Internal users report any usability issues or improvement suggestions for the tools.	Insufficient engagement may result in minimal feedback to refine the tools, usability issues may remain unidentified, while suggestions for improving the tools may be missed. This could weaken the impact and scalability of these solutions, as the lack of experienced input from tool operators would make a wider adoption of the tools harder.

NILM awareness	Pilot participants monitor their household consumption disaggregated per home appliance. They gather information regarding their appliance's energy efficiency labels. They also consult information regarding the flexibility activations for their household.	NILM app can access the smart meter data from the domestic users with enough granularity and the end-users introduce the type of assets available in their households.	Low engagement at technical level won't have a big impact, but we would lose feedback regarding user satisfaction leading to lower info availability for WP7 social and economic assessment.

Engagement so far

The Greek pilot team has initiated some engagement activities to support the above assumptions:

- **User information hub**, an online information hub launched for interested end-users to register (via mailing list) and receive updates about the Greek pilot of OPENTUNITY. This has attracted several potential participants, indicating public curiosity about local flexibility opportunities and new grid technologies. The hub and mailing list serve to keep users informed and invested.
- **Surveys/workshops (planned)**, to gauge participants' energy behaviour, their trust and willingness in allowing remote control of appliances and gather feedback on tools. The pilot plans to deploy questionnaires and interactive workshops as the demonstration begins.
- **Internal HEDNO engagement**, to introduce OPENTUNITY tools under development to key departments (e.g. grid operations, planning, IT). The aim of these internal briefings is to recognize the importance of HEDNO's and IPTO's staff and start familiarizing operators with the new systems.

Actions to ensure assumptions are met

To mitigate the risks above and strengthen the likelihood of meeting user-related assumptions, the Greek pilot is implementing several measures:

- **Simplified and to incentivize feedback** with very short surveys for NILM end-users, to quickly capture satisfaction and any discrepancies in appliance detection. Similarly, LFM participants will receive simple feedback forms after activation events.
- **Building trust and awareness** through regular communication and education, since offering flexibility can be unfamiliar or concerning to some. This includes sending out update newsletters via the information hub, highlighting success stories (e.g. a participant who saved X € or reduced Y kg CO_2 by participating) and addressing common concerns in plain language. Virtual workshops (physical or virtual) will be held where participants can talk with the project team and FSPs, ask questions, and feel heard.
- **Support for HEDNO staff** for the DSO-internal tools. The project will continue to engage HEDNO's teams through training sessions and iterative development. By involving the end-users in tool refinement, the tools will better fit their needs. The pilot will also demonstrate quick wins and strategic impacts, for instance showing the deployment of dynamic line rating can increase the capacity of a line (in comparison to static thermal rating), or how the use of flexibility can affect the deferral of grid investments.

3.2 Deployment plan

Table 3.6. GR pilot deployment plan. The dashed red line represents the start of OPENTUNITY demonstrations.

Greek pilot site deployment	2023	2024												2025											
	Jan - Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	M01 - M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	M25	M26	M27	M28	M29	M30	M31	M32	M33	M34	M35	M36
Flexibility market use cases																									
Planning- Designing DSO-TSO coordination		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■									
Integration of Greek pilot site in NODES platform				■	■	■	■	■	■	■	■	■	■	■	■	■									
Testing scenarios on NODES platform						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
Planning Citizen Engagement Activities													■	■	■										
Citizen Engagement Activities																■	■	■	■	■	■	■	■	■	
Participants onboarding																	■	■	■	■	■	■	■	■	
Planning and installing equipment																■	■	■	■	■					
Initial pilot deployment																		■	■						
Feedback gathering																			■	■	■	■	■	■	
Grid-focused use cases																									
Data collection (GIS, SCADA, metering, failure, historical)				■	■	■	■	■	■	■	■	■	■	■	■	■									
Data processing						■	■	■	■	■	■	■	■	■	■	■									
Historical data provision to ICCS									■	■	■	■	■	■	■	■									
Data provision to ICCS via MQTT													■	■	■	■	■	■	■	■	■	■	■	■	■
Equipment definition									■	■	■	■	■	■	■	■									
Equipment installation																	■	■	■	■	■	■	■	■	■
Tools utilization and feedback																■	■	■	■	■	■	■	■	■	■

3.3 Test cases, datasets and KPIs

3.3.1 Test cases

In the Greek pilot, 12 test cases will be demonstrated, their short descriptions are provided below and the full descriptions are included in Annex 1 (section 10.1.1).

Table 3.7. Summary of GR pilot's test cases

Category	Test case ID	Test case name
Horizontal	TC1.2.4	NILM identification ability (GR pilot)
	TC1.3.4	State estimation accuracy (GR pilot)
	TC1.4.2	RTTR tool for MV line capacity calculation (GR pilot)
	TC1.5.3	Short-term asset management for UHV/HV transformers (GR pilot)
	TC1.6.3	Topology identification capability (GR pilot)
	TC1.7.2	Network planning tool for investment deferral (GR pilot)
	TC1.8.1.1	Baseline consumption forecast (GR pilot)
	TC1.8.2.1	Flexibility consumption forecast (GR pilot)
	TC1.8.3.1	Dispatch of control signals to assets (GR pilot) (GR pilot)
	TC1.9.1	Registration of consumers' preferences
	TC1.10.1	Flexibility procurement in an integrated market (GR pilot)
Pilot-specific	TC2.1.1	Network planning tool for optimal upgrades under budget constraints

TC1.2.4 NILM identification ability (GR pilot)

Short description: This test case analyzes the ability of the NILM module to identify the different loads of a households using just the RT smart meter data as an input.

Main responsible partners:

- HYP (consumption data provider)
- ETRA (NILM developer)

Involved assets & systems:

- Smart meter
- Consumption sensors
- Smart home gateway
- NILM module

Environment: Live

TC1.3.4 State estimation accuracy (GR pilot)

Short description: This test case demonstrates the accuracy of the Distribution System State Estimation (DSSE) tool in enhancing MV grid observability from primary substations to service transformer level. The tool applies a deep neural network (DNN), trained on historical data and validated through real-time PMU and AMI measurements, to estimate nodal voltages and line power flows.

Main responsible partners:

- HEDNO (DSO, data provider)
- ICCS (technology provider, DSSE software and hosting)

Involved assets & systems:

- DSSE software (ICCS server)
- SCADA system (primary substation measurements)
- AMI/AMR system (load and DER measurements)
- PMUs and Phasor Data Concentrator (MV/LV transformers)
- TI tool (providing operating grid topology)

Environment: Hybrid – offline learning with historical/topology datasets combined with live operational PMU and AMI measurements.

TC1.4.2 RTTR tool for MV line capacity calculation (GR pilot)

Short description: Showcase the RTTR tool as a low-cost solution for DSOs to dynamically assess MV line capacity. The tool combines historical current data, real-time measurements, and high-resolution weather forecasts with machine learning models to estimate conductor temperature and probabilistic short-term ampacity (up to 6 hours).

Main responsible partners:

- HEDNO (DSO, end-user)
- ICCS (developer and operator of RTTR tool)

Involved assets & systems:

- RTTR software and GUI (ICCS server, database).
- Sentrisense Line Guard devices (real-time conductor monitoring)
- SCADA system (line currents)
- Sentrisense API, IoT MQTT broker
- Weather forecast services (temperature, wind, solar radiation)
- User-uploaded topology and historical datasets (CSV)

Environment: Hybrid – a blend of offline learning using historical and topology data, integrated with live data from SCADA systems, and weather APIs.

TC1.5.3 Short-term asset management for UHV/HV transformers (GR pilot)

Short description: Demonstrate the short-term module of the advanced asset management tool to monitor transformer condition. The module performs Dissolved Gas Analysis (DGA), top oil temperature anomaly detection and prediction, and bushing insulation assessment. It raises alarms, stores historical records, and forecasts critical conditions with associated failure probabilities.

Main responsible partners:

- IPTO (Greek TSO, user of the tool)
- ICCS (developer and operator of the asset management tool)

Involved assets & systems:

- UHV/HV transformers with on-line monitoring systems (OLMS)
- Asset Management Tool and GUI (ICCS server, database)
- OLMS data interface (SFTP) for uploads

Environment: Hybrid – historical OLMS data (CSV) combined with OLMS streams for real-time alarms and short-term (6h) predictions.

TC1.6.3 Topology identification capability (GR pilot)

Short description: Demonstrate the ability of the TI tool to determine the operating grid topology by identifying the status of all switching devices. The tool applies a DNN trained on historical/topology data and uses real-time PMU/AMI measurements to identify the MV grid's node-branch configuration.

Main responsible partners:

- HEDNO (DSO, data provider)
- ICCS (technology provider, TI software and hosting)

Involved assets & systems:

- TI software (ICCS server)
- SCADA system (substation measurements)
- AMI/AMR system (load and DER measurements)
- PMUs and Phasor Data Concentrator (MV/LV transformers)

Environment: Hybrid – offline DNN training with historical datasets combined with live real-time PMU and AMI measurements.

TC1.7.2 Network planning tool for investment deferral (GR pilot)

Short description: Demonstrate the use of the network planning tool to defer distribution network investments by identifying the most cost-effective mix of flexibility (RES, storage, demand response). By optimizing these options, the tool minimizes investment needs while maintaining system reliability.

Main responsible partners:

- HEDNO (DSO, tool user)
- ICCS (developer of the planning tool)

Involved assets & systems:

- Network Planning Tool (software and GUI)
- Feeder topology data (JSON)
- Demand/load profiles (CSV, hourly resolution per secondary substation)
- Power factor data (CSV)
- Candidate line upgrade dataset (CSV)

Environment: Hybrid – offline historical demand datasets and existing topology with user-defined economic and flexibility parameters; optimization engine computes investment deferral scenarios.

TC1.8.1.1 Baseline consumption forecast (GR pilot)

Short description: Demonstrate the capability of the BFMS to generate baseline day-ahead consumption forecasts per asset. Using historical consumption data and machine learning models, the tool produces baseline profiles stored for future use in flexibility markets.

Main responsible partners:

- HYP (BFMS partner & Greek pilot operator)
- QUE (Data Space operator)

Involved assets & systems:

- Pilot site assets with EMS (SMART BOX)
- BFMS
- Data Space (connector at participant sites)

Environment: Hybrid – live EMS consumption data combined with historical profiles; BFMS generates baseline forecasts stored in Profiling Service.

TC1.8.2.1 Flexibility consumption forecast (GR pilot)

Short description: Showcase the BFMS functionality to generate day-ahead flexibility consumption forecasts per asset. Building on baseline forecasts and, where available, market price data and user-defined constraints, the tool produces flexibility profiles stored for use in market bidding.

Main responsible partners:

- HYP (BFMS partner & Greek pilot operator)
- QUE (Data Space operator)

Involved assets & systems:

- Pilot site assets with EMS
- BFMS
- Data Space (connector at participant sites)

Environment: Live

TC1.8.3.1 Dispatch of control signals to assets (GR pilot)

Short description: Demonstrate the end-to-end process of dispatching control signals to controllable assets at pilot sites. After forecasts are generated and bids are matched on the NODES platform, the BFMS generates and sends control sequences to assets over the Data Space.

Main responsible partners:

- HYP (BFMS partner & Greek pilot operator)
- NODES (market platform operator)
- QUE (Data Space operator)

Involved assets & systems:

- BFMS
- NODES platform
- Data Space (connector at pilot sites)
- Pilot site assets with EMS

Environment: Hybrid – live flexibility forecasts integrated with NODES market orders; BFMS dispatches control signals via Data Space.

TC1.9.1 Registration of consumers' preferences (GR pilot)

Short description: Demonstrate the ability of the BFMS to register and store consumer preferences per asset. Consumers log in via the demand response (DR) initialization service UI, view their assets, and submit preferences, which are stored by the BFMS for integration into demand response algorithms.

Main responsible partners:

- HYP (Greek pilot operator & BFMS partner)
- QUE (Data Space operator)

Involved assets & systems:

- Pilot site assets with EMS
- BFMS
- Data Space

Environment: Hybrid – live consumer interaction through DR UI combined with EMS–BFMS communication; preferences stored in BFMS.

TC1.10.1 Flexibility procurement in an integrated market (GR pilot)

Short description: Demonstrate a secure, transparent, and scalable coordination strategy between the Greek TSO (IPTO) and DSO (HEDNO) within a unified flexibility market. The pilot tests simultaneous flexibility activation across grid levels using NODES as the trading platform, with multiple market rounds and alternative coordination schemes.

Main responsible partners:

- HEDNO (DSO)
- IPTO (TSO)
- HYP (FSP)
- ICCS (FSP)
- NODES (market platform operator)

Involved assets & systems:

- Residential assets
- Virtual batteries
- Solar plants
- NODES platform

Environment: Live – TSO, DSO and FSPs trading flexibility via NODES, testing manual, automatic, and continuous rounds with alternative coordination scenarios.

TC2.1.1 Network planning tool for optimal upgrades under budget constraints

Short description: Demonstrate the network planning tool's ability to identify the most cost-effective grid upgrades under budget constraints that maximize RES hosting capacity. The tool integrates flexibility parameters, demand/load profiles, and economic limits to provide DSOs with an optimized list of upgrades and associated costs, alongside the resulting RES capacity increase.

Main responsible partners:

- HEDNO (DSO, tool user)
- ICCS (developer of the planning tool)

Involved assets & systems:

- Network Planning Tool (software and GUI, ICCS server)
- Feeder topology (JSON)
- Demand/load profiles (CSV, hourly resolution)
- Power factor data (CSV)
- Candidate line upgrade dataset (CSV)

Environment: Hybrid – historical demand datasets and existing topology combined with user-defined budget, flexibility, and economic parameters in the planning tool's optimization engine.

3.3.2 Datasets

Table 3.8. Datasets provided by GR pilot for test cases

Dataset ID	Dataset name
DS.GR.01	Network data of the Greek demo distribution grid
DS.GR.02	Multi-source, conventional measurements collected from Greek demo distribution grid
DS.GR.03	PMU measurements collected from Greek demo distribution grid
DS.GR.04	Real-time feeder operational data
DS.GR.05	Topological data of the lines
DS.GR.06	Historical current measurements
DS.GR.07	Real-time line operational data
DS.GR.08	Environmental forecasts
DS.GR.09	Transformer historical monitoring data
DS.GR.10	Transformer monitoring data from OLMS
DS.GR.11	Load profile (power curves)
DS.GR.12	Substation power factor data (cosφ)
DS.GR.13	Information on the lines that will be considered for possible upgrade
DS.GR.14	Distribution network topology
DS.GR.15	Asset power consumption
DS.GR.16	Asset baseline power consumption forecast
DS.GR.17	Asset flexibility power consumption forecast
DS.GR.18	Control signals to assets at pilot sites
DS.GR.19	Consumers' preferences per asset
DS.GR.20	Asset data

Table 3.9. GR pilot mapping datasets with test cases

		Test cases											
		1.2.4	1.3.4	1.4.2	1.5.3	1.6.3	1.7.2	1.8.1.1	1.8.2.1	1.8.3.1	1.9.1	1.10.1	2.1.1
Datasets	DS.GR.01												
	DS.GR.02												
	DS.GR.03												
	DS.GR.04												
	DS.GR.05												
	DS.GR.06												
	DS.GR.07												
	DS.GR.08												
	DS.GR.09												
	DS.GR.10												
	DS.GR.11												
	DS.GR.12												
	DS.GR.13												
	DS.GR.14												
	DS.GR.15												
	DS.GR.16												
	DS.GR.17												
	DS.GR.18												
	DS.GR.19												
	DS.GR.20												

3.3.3 KPIs

3.3.3.1 Summary and mapping of GR pilot KPIs

Table 3.10. Summary of GR pilot's KPIs actions

New KPI ID	Old KPI ID	Title	Action	Comment
KPI.GR.01	-	Measurement-consistent mean absolute percentage error	Added	Loosely based on KPI_03, defined a new KPI to evaluate the state estimation tool adapted to the Greek pilot
KPI.GR.02	-	Topology match accuracy	Added	Defined a new KPI to evaluate the topology identification tool adapted to the Greek pilot
-	KPI_08	Increase in RES penetration	Removed	Already calculated by KPI.GPO.04
KPI.RTTR.01	KPI_04	Capacity increase by DLR	Updated	Corrected a typo in the measurement unit
KPI.RTTR.02	KPI_05	Maximum line temperature underestimation	Kept	-
KPI.AAM.01	KPI_06	Accuracy on asset condition	Updated	Included TSO
KPI.GPO.01	KPI_09	Investment deferral	Kept	-
KPI.GPO.02	KPI_18	Cost reduction due to deferral of grid upgrade	Updated	Corrected minor typos in the KPI description and updated the calculation steps
KPI.GPO.03	KPI_43	Decrease in investment costs	Updated	Corrected minor typos
KPI.GPO.04	KPI_26	Increase in RES hosting capacity	Updated	Corrected minor typos
KPI.NILM.01	KPI_02	NILM F1	Kept	-
KPI.HEMS.01	KPI_10	Demand forecasting accuracy	Kept	-
KPI.HEMS.02	KPI_11	Flexibility delivery precision	Kept	-
KPI.HEMS.03	KPI_12	Flexibility potential	Kept	-
KPI.HEMS.04	KPI_13	GHG reduction	Kept	-
KPI.HEMS.05	KPI_14	Load reduction/increase	Kept	-
KPI.HEMS.06	KPI_15	Rate of successful DR events	Kept	-
KPI.HEMS.07	KPI_16	Thermal comfort violation	Updated	More accurate representation of thermal comfort
KPI.FM.01	KPI_17	Local average voltage deviation index	Updated	Defined HEDNO as the responsible partner
KPI.FM.02	KPI_20	TSO-DSO coordination efficiency	Updated	Updated to reflect the TSO – DSO common participation in the LFM for the Greek pilot
KPI.FM.04	KPI_22	Type of flexibility providers	Kept	-
KPI.FM.05	KPI_24	Flexibility used for ancillary services and balancing	Updated	Updated to reflect the TSO participation in the LFM for the Greek pilot

Table 3.11. GR pilot mapping KPIs with test cases

		Test cases											
KPIs		1.2.4	1.3.4	1.4.2	1.5.3	1.6.3	1.7.2	1.8.1.1	1.8.2.1	1.8.3.1	1.9.1	1.10.1	2.1.1
	KPI.GR.01		■										
	KPI.GR.02					■							
	KPI.RTTR.01			■									
	KPI.RTTR.02			■									
	KPI.AAM.01				■								
	KPI.GPO.01						■						
	KPI.GPO.02						■						
	KPI.GPO.03						■						
	KPI.GPO.04												■
	KPI.NILM.01	■											
	KPI.HEMS.01							■					
	KPI.HEMS.02									■		■	
	KPI.HEMS.03							■	■			■	
	KPI.HEMS.04								■	■			
	KPI.HEMS.05								■	■			
	KPI.HEMS.06									■			
	KPI.HEMS.07										■		
	KPI.FM.01											■	
	KPI.FM.02											■	
	KPI.FM.04											■	
	KPI.FM.05											■	

Table 3.12. GR pilot mapping KPIs with strategic objectives

		KPIs																				
Strategic objectives		KPI.GR.01	KPI.GR.02	KPI.RTTR.01	KPI.RTTR.02	KPI.AAM.01	KPI.GPO.01	KPI.GPO.02	KPI.GPO.03	KPI.GPO.04	KPI.NILM.01	KPI.HEMS.01	KPI.HEMS.02	KPI.HEMS.03	KPI.HEMS.04	KPI.HEMS.05	KPI.HEMS.06	KPI.HEMS.07	KPI.FM.01	KPI.FM.02	KPI.FM.04	KPI.FM.05
	SO1. Decarbonization of EU society			■	■		■		■	■												
	SO2 Citizen and stakeholder empowerment										■	■	■	■	■	■	■	■	■		■	■
	SO3 Ensure quality of supply in a context of increase of RES	■	■	■	■	■	■	■	■	■										■		

3.3.3.2 Pilot site baseline overview

Each KPI related to the Greek pilot needs to be calculated after demonstrations and benchmarked with state-of-the art or business as usual (BAU) figures. We present here the baseline methodology selected for each KPI, with its value (or expected value) marked in **orange**. When OPENTUNITY innovation tools are expected to bring a relevant improvement, we also argue for our estimated target, marked in **red**.

KPI.GR.01 State estimation accuracy

The flat-profile baseline assumes all bus voltages are set to 1.0 p.u. with zero phase angles, and the implied measurements are obtained via power flow. This provides a clearly defined and operationally simple baseline that highlights the mismatch between the naive nominal assumption and the actual system measurements. While such a flat assumption can be reasonably close for voltage magnitudes in typical distribution networks (where voltages hover near 1.0 p.u.), the presence of distributed generation, long feeders, or heavy loading conditions tends to increase errors. For the Greek demo pilot site, a fair expectation is that this baseline yields MC-MAPE values in the range of **10–15%**, making it a suitable lower reference for assessing the added value of the proposed state estimator.

KPI.GR.02 Topology identification accuracy

The persistence baseline assumes no topology inference is carried out and the topology at each evaluated case is taken equal to the normal or last known operating topology from the HEDNO control centre. In typical distribution networks, switch operations are infrequent. So, it is an operationally realistic baseline (many operators assume topology persists until a change is observed). Given that the Greek demo pilot site is a distribution grid with a modest number of PVs at MV level, it is safe to assume that topology changes (including PV disconnection) occur in less than 10% of intervals. Under this assumption, the persistence approach yields a TMA value close to **90%**.

KPI.RTTR.01 Capacity increase by DLR

System operators use Static Thermal Rating with conservative weather assumptions to ensure network security under all operating conditions. By fixing high ambient temperature and low wind speed, the approach avoids the risk of thermal overloading, but at the cost of significant underutilization of the actual line capacity. While overhead lines are constructed to endure the peak summer conditions, they frequently operate under less severe weather for most of the year, allowing for potential increases in line capacity by up to 200%. According to ENTSO-E, traditional static thermal ratings for overhead lines are determined under conservative assumptions – typically set for worst-case summer conditions (e.g., ambient ~40 °C, wind ~0.6 m/s, high solar gain) – ensuring network security in the absence of real-time monitoring. The KPI is defined as follows:

$$\Delta P_{av}^{max} = \sqrt{3}\, V_{nom} \frac{\sum_{i=1}^{N} I_{max,\ dynamic} - I_{max,\ static}}{N}$$

Where:

- $I_{max,\ dynamic}$: 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

When the RTTR tool is not applied (i.e. baseline), the line ampacity of the line in the abovementioned formula for the calculation of ΔP_{av}^{max}, is the same as the static line rating, thus their difference – i.e. the KPI baseline – is calculated as **zero**.

KPI.RTTR.02 Maximum line temperature underestimation

In practice, system operators rarely measure conductor or cable temperatures along the entire network. Without Real-Time Thermal Rating, they rely on deterministic, conservative approaches to ensure the assets are never overloaded. For this study, the baseline scenario used to calculate the

Static Thermal Rating (STR) assumes a maximum allowable conductor temperature of T_max = 85˚C[1], which sets the thermal limit for this baseline scenario. This approach, consistent with methodologies employed by system operators, uses fixed, worst-case weather conditions:

- Ambient air temperature: Ta=45˚C
- Wind speed at conductor height: m/sv=0.6 m/s
- Wind–conductor yaw angle: θ=90°
- Global solar irradiance: W/m²G=1000 W/m²
- Conductor surface emissivity: ε=0.9
- Solar absorptivity: αs=0.5

This baseline scenario represents the conventional STR approach, ensuring network security under worst-case environmental conditions without real-time adjustments.

The KPI is calculated as:

$$Max\ Temperature\ Underestimation(\mathrm{C}^{o}) = \max_{i=1:N}(|T_{measured} - T_{\mathrm{estimated}}|)I_i$$

Where:

- $T_{\mathrm{estimated}}$: 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: Binary with 0 if the temperature is overestimated, 1 if underestimated

In the abovementioned formula, T_max = 85˚C can be considered as $T_{\mathrm{estimated}}$. Installation of the relevant measuring equipment is still pending in the Greek pilot site. Once actual data from HEDNO's line are provided, the baseline will be calculated, considering the method applied for this KPI (KPI.RTTR.02) in the Spanish pilot site.

KPI.AAM.01 Accuracy on asset condition

The KPI is defined as follows:

$$Accuracy = 100\frac{\sum_{i=1}^{N} I}{N}$$

Where:

- I: Binary equal to 1 if for asset *i* if the prediction condition category is the actual category provided by the DSO
- *N:* Number of samples

Since the OPENTUNITY advanced management tool is not applied yet, the baseline for this KPI is **0**.

KPI.GPO.01 Investment deferral

The KPI is defined as follows:

$$\Delta T = \mathrm{T_{R\&I}} - \mathrm{T_{base}}$$

Where:

- $\mathrm{T_{base}}$: Time of investment in years, in the BAU scenario.
- $\mathrm{T_{R\&I}}$: Time of investment in years, when flexibility is installed and optimized.

When the tool is not applied (i.e. baseline), $\mathrm{T_{R\&I}}$ will be equal to $\mathrm{T_{base}}$. Thus, according to the aforementioned formula for the calculation of the KPI, the baseline for this KPI is **0**.

KPI.GPO.02 Cost reduction due to deferral of grid upgrade

[1] Additional information for the relevant calculations is provided in D5.1 – OPENTUNITY power flow developments (v1) [4]

The KPI is defined as follows:

$$Cost_{reduction} = \frac{Cost_{BAU} - Cost_{Flexibility}}{Cost_{BAU}} \cdot 100$$

Where:

- $Cost_{reduction}$: Reinforcement cost when not upgrading the power grid due to utilization of the local flexibility market.
- $Cost_{BAU}$: Reinforcement cost in the BAU scenario.
- $Cost_{Flexibility}$: Grid reinforcement cost when considering the use of flexibility.

When the tool is not applied (i.e. baseline), $Cost_{BAU}$ will be equal to $Cost_{Flexibility}$. Thus, according to the abovementioned formula for the calculation of the $Cost_{reduction}$, the baseline for this KPI is **0**.

KPI.GPO.03 Decrease in investment costs

The KPI is defined as follows:

$$\Delta P_{RES} = 100 \frac{C_{BAU} - C_{R\&I}}{C_{BAU}}$$

Where:

- $C_{R\&I}$: Cost of network upgrades estimated in the pilot with optimal scheduling of flexibility and network investments.
- C_{BAU}: Cost of network upgrades estimated with existing methodologies applied in each pilot.

When the planning tool is not applied (i.e. baseline), $C_{R\&I}$ will be equal to the cost of BAU scenario, C_{BAU}. Thus, according to the abovementioned formula for the calculation of ΔP_{RES}, the baseline for this KPI is **0**.

KPI.GPO.04 Increase in RES hosting capacity

The KPI is defined as follows:

$$\Delta C_{RES} = 100 \frac{\mathrm{RES}_{\mathrm{capacity}_{R\&I}} - \mathrm{RES}_{\mathrm{capacity}_{BaU}}}{\mathrm{RES}_{\mathrm{capacity}_{BaU}}}$$

Where:

- $\mathrm{RES}_{\mathrm{capacity}_{R\&I}}$: Penetration of renewables with network planning that considers flexibility optimization
- $\mathrm{RES}_{\mathrm{capacity}_{BaU}}$: Penetration of renewables with network planning in a BAU scenario.

When the network planning tool is not applied (i.e. baseline), the $\mathrm{RES}_{\mathrm{capacity}_{R\&I}}$ in the calculation of ΔC_{RES} will be the same with the business as usual scenario, $\mathrm{RES}_{\mathrm{capacity}_{BaU}}$. Thus, the KPI value for the baseline is equal to **0**.

KPI.NILM.01 NILM F1

Currently, there is no method for disaggregating energy consumption data in place in the pilots, so the project is providing a new service that opens the door to new impacts. In terms of technical performance, there are Spanish grid utilities that have their own disaggregation methods and reach 80% of accuracy. Considering this value and to further improve the performance, the baseline for OPENTUNITY has been set to **80%**. F1 score, which considers the accuracy, precision and recall of the classes to predict (ON and OFF detections) calculated in this KPI could be increased in the project to **at least 85% on average**, considering each appliance monitored.

KPI.HEMS.01 Demand forecasting accuracy

As described in D2.1, this KPI is calculated using the following formula:

$$MAE_{forecast} = \frac{\sum_{t=1}^{T} \left| P_{act,t} - P_{b,t} \right|}{T}$$

Where:

- $MAE_{forecast}$: mean absolute error between the actual and the forecasted demand (baseline power consumption), 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 ($t \in 1, \dots, T$)

To calculate the baseline value for this KPI, one should consider that the tool (BFMS) is not applied. In the absence of the BFMS, the baseline power consumption is considered equal to the power consumption of the previous day. The KPI is then calculated by subtracting the day before power consumption from the actual power consumption for the day of interest and for the same timeframe. **This value changes dynamically every day, based on the asset, the season and the occupant preferences**.

KPI.HEMS.02 Flexibility delivery precision

The baseline for the delivery precision evaluation is the traded volume, i.e. flexibility volume resulting from the matching of the buy request by the DSO and TSO and flexibility offer from the FSP. The deviation between the baseline and the metering data serves to quantify the delivery percentage, with 100% indicating non-delivery. **No baseline** is available before testing since no flexibility activation is in place in the pilot.

KPI.HEMS.03 Flexibility potential

The flexibility potential of an asset is calculated using actual metering data. The resulting baseline for flexibility trading is the consumption or production profile without activation of flexibility, i.e. **0 kWh**.

KPI.HEMS.04 GHG reduction

As described in D2.1, this KPI is calculated using the following formula:

$$GHG_{Reduction} = EF \cdot \sum_{t=1}^{T} \left(P_{act,t} - P_{DR,t}\right)$$

Where:

- $GHG_{Reduction}$: 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 ($t \in 1, \dots, T$)

To calculate the baseline value for this KPI, one should consider that the tool (BFMS) is not applied. In the absence of the BFMS, the adjusted power consumption is considered equal to the actual power consumption. This results in a **0 gCO_2eq GHG** reduction for the baseline scenario of this KPI.

KPI.HEMS.05 Load reduction/increase

As described in D2.1, this KPI is calculated using the following formula:

$$E_{change} = \sum_{t=1}^{T} \left(P_{act,t} - P_{DR,t}\right)$$

Where:

- 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 ($t \in 1, \ldots, T$)

To calculate the baseline value for this KPI, one should consider that the tool (BFMS) is not applied. In the absence of the BFMS, the adjusted power consumption is considered equal to the actual power consumption. This results in a **0 kWh** load reduction/increase for the baseline scenario of this KPI.

KPI.HEMS.06 Rate of successful DR events

As described in D2.1, this KPI is calculated using the following formula:

$$R_{S,DR} = \frac{N_{S,DR}}{N_{total,DR}} \cdot 100\%$$

Where:

- $R_{S,DR}$: rate of successful DR events (percentage)
- $N_{S,DR}$: number of successful DR events
- $N_{total,DR}$: number of total DR requests

To calculate the baseline value for this KPI, one should consider that the tool (BFMS) is not applied. In the absence of the BFMS, the number of successful DR events is considered equal to zero. This results in a **0%** rate of successful DR events for the baseline scenario of this KPI.

KPI.HEMS.07 Thermal comfort violation

A minor modification to this KPI has been made (compared to D2.1) for a more accurate representation of the thermal comfort. For completeness, the KPI is presented in Annex I. Based on the updated version, the KPI calculation formula is as follows:

Where:

$$TC = \sum_{t=1}^{T} (\theta_{limit,l,t} - \theta_{actual,t}) \cdot I_{l,t} \cdot \Delta t + \sum_{t=1}^{T} (\theta_{actual,t} - \theta_{limit,u,t}) \cdot I_{u,t} \cdot \Delta t$$

- 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
- $\theta_{limit,l,t}$: lower temperature limit at time t
- $\theta_{limit,u,t}$: upper temperature limit at time t
- $I_{l,t}$: indicator variable which shows the existence of a lower temperature limit violation at time t (can be either zero or one). 0: above lower limit. 1: below lower limit.
- $I_{u,t}$: indicator variable which shows the existence of an upper temperature limit violation at time t (can be either zero or one). 0: below upper limit. 1: above upper limit.
- *t*: time index ($t \in 1, \ldots, T$)

To calculate the baseline value for this KPI, one should consider that the tool (BFMS) is not applied. In this case, it can be assumed that the actual temperature is equal to the temperature set by the occupant, which in turn is within the upper and lower temperature limits set by the occupant. This results in a **0°C·h** thermal comfort violation for the baseline scenario of this KPI.

KPI.FM.01 Local average voltage deviation index

This KPI is introduced to measure the voltage in the part of the distribution network where flexibility services will be activated. The objective is that the activation of flexibility should maintain the average voltage at the system buses within +/- 0.05 pu of the nominal operating value (i.e. the target is AVDI **< 0.05 pu**). As a starting point, we assume that voltage issues occur when flexibility is not activated, leading to **AVDI>=0.05 pu**.

KPI.FM.02 TSO-DSO coordination efficiency

Without coordination, submitted offers would just be activated when corresponding flexibility buy orders match. The integrated coordination mechanisms serve to reduce the number of grid violations deriving from two buyers offering into the market. The coordination efficiency will be measured by two KPIs: the ratio of solved violations and the portion of provided flexibility volume. Due to the current lack of a common flexibility market and a coordination mechanism for the joint participation of HEDNO and IPTO, the baseline values of both indicators are considered to be **0**.

KPI.FM.04 Type of flexibility providers

The metric for the KPI measures the proportion of different types of available technologies in the region of the Greek pilot which can be utilized. Local flexibility as well as flexibility from distributed assets such as households has never been used before, leading to a baseline of **0%**.

KPI.FM.05 Flexibility used for ancillary services and balancing

This KPI will define the ratio of activated flexibility from the system operators' perspective, used to resolve congestion and balancing issues once the Local Flexibility Market becomes operational. The calculation will be based on the amount of flexibility identified as needed by the system operators locally and supplied through the FSP offers in the LFM.

For DSO requests, LFMs are still developing, but a **50%** initial activation ratio of requested flexibility is within the range suggested by ongoing pilot markets and market maturity assessments.

TSOs generally operate at a higher system level. In LFMs, TSO requests for flexibility are typically fewer than those of DSOs and often constrained by coordination complexities. Early-stage expectations around **10%** activation ratios align with the limited but growing role of TSO activation at this level

3.4 Demonstration plan

Table 3.13. GR pilot demonstration plan. The dashed red lines represent the start and end of OPENTUNITY demonstrations.

Greek pilot demonstration plan	2025					2026								
	Jan 2023 - Aug 2025	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	M01-M32	M33	M34	M35	M36	M37	M38	M39	M40	M41	M42	M43	M44	M45
TC1.2.4 NILM identification ability														
Agree on the test conditions				■	■									
Sign an agreement with the end-user to test the solution			■	■										
Internal tests on the pilot site to check gather 1-min data					■	■								
Collect historical data (1 month)				■										
First test						■	■	■	■					
Preliminary results analysis and adjustments							■	■	■					
Second test										■	■			
KPI calculations and reporting											■	■	■	
TC1.3.4 State estimation accuracy														
Integration of pilot data and data sources		■	■	■	■									
Model training (offline learning stage)					■									
Deployment/Integration of ICCS state estimation tool					■	■								
Tool testing and performance review (real-time operation stage)							■	■	■	■	■			
KPI evaluation and analysis										■	■	■	■	■
TC1.4.2 RTTR tool for MV line capacity calculation														
Integration of pilot's data and data sources		■	■											
Models training				■										
Deployment/Integration of ICCS RTTR tool				■	■	■								
Tool testing and performance review							■	■	■	■	■			
KPI evaluation and analysis									■	■	■	■	■	■
TC1.5.3 Short term asset management for UHV/HV transformers														
Integration of pilot's data and data sources		■	■											
Models training				■										
Deployment/Integration of ICCS long-term asset management tool				■	■									
Tool testing and performance review						■	■	■	■	■	■			
KPI evaluation and analysis									■	■	■	■	■	■
TC1.6.3 Topology identification capability														
Integration of pilot data and data sources		■	■	■	■									
Model training (offline learning stage)					■									
Deployment/Integration of ICCS topology identification tool					■	■								
Tool testing and performance review (real-time operation stage)							■	■	■	■	■			
KPI evaluation and analysis										■	■	■	■	■
TC1.7.2 Network planning tool for investment deferral														

Integration of pilot's data and data sources
Deployment/Integration of ICCS network planning tool
Tool testing and performance review
KPI evaluation and analysis
TC1.8.1.1 Baseline consumption forecast
Asset consumption data collection from the pilot
BFMS training and testing
Integration with NODES platform
Operational phase within the pilot demonstration
KPI evaluation and analysis
TC1.8.2.1 Flexibility consumption forecast
BFMS training and testing
Integration with NODES platforms
Operational phase within the pilot demonstration
KPI evaluation and analysis
TC1.8.3.1 Dispatch of control signals to assets
Integration with NODES platforms
Operational phase within the pilot demonstration
KPI evaluation and analysis
TC1.9.1 Registration of consumers' preferences
Assets configuration to BFMS
Participants' preferences registration
KPI evaluation and analysis
TC1.10.1 Flexibility procurement in an integrated market
KPI calculation (visualization and monitoring dashboard is already provided by NODES as market operator)
Onboarding on platform (Grid and flexibility assets replication on NODES platform, by DSO, TSO, and FSPs)
General testing of the NODES market functionalities
Testing of the coordination schemes
KPI evaluation and analysis
TC2.1.1 Network planning for optimal upgrades under budget constraints
Integration of pilot's data and data sources
Deployment/Integration of ICCS network planning tool
Tool testing and performance review
KPI evaluation and analysis

3.5 Risk management plan

Table 3.14. GR pilot risk management plan

Risk ID	Risk description	Category	Likelihood	Impact	Mitigation/contingency action
GR.01	In the Greek pilot, the flexibility market under development will allow FSPs to trade power and support system needs. Yet, the absence of real-time communication and control systems between end-users, FSPs, and DSO smart meters poses a risk, as flexibility delivery cannot be fully validated. In addition, limited TSO–DSO coordination may cause congestion or balancing issues across HV, MV, and LV levels. These gaps could delay order execution, hinder validation of services, and reduce the project's impact and future exploitation potential.	Technical	Medium	Medium	The communication challenge between HEDNO and IPTO has been addressed by integrating the NODES communication toolbox into the platform. As a fallback, manual communication will be used: FSPs will notify end-users via phone or text, and users will adjust their loads accordingly. The DSO will rely on existing metering infrastructure to verify delivered flexibility. Although not ideal, this interim approach enables demonstration of real-world procedures. For TSO–DSO coordination, an analytic scheme will be applied through the NODES flexibility market platform.
GR.02	Several tools require comprehensive datasets, but gaps may arise from smart meters and sensors faults, connection issues, or limited user engagement. Insufficient data would affect tool evaluation, reduce demonstration effectiveness, and compromise the project's outcomes.	Technical	Low / Medium	Medium	Existing and historical data will supplement sensor inputs, ensuring adequate coverage for tool evaluation. A significant volume of historical data has already been gathered, and the rest of the data will be provided by the new equipment. The number of smart meters is also expected to grow by project end. A monitoring tool will detect equipment or connection issues, supporting reliable demonstration activities.
GR.03	Limited availability of synchronized measurement data (current, weather, and temperature) may restrict full validation of the RTTR tool across different operational regimes.	Technical	Low	Low	Combine on-site data with simulated scenarios to enrich validation coverage. Use uncertainty quantification to document confidence intervals in model performance.
GR.04	Limited PMUs could lead to less comprehensive data coverage, affecting the robustness of the state estimation.	Technical	Low	Low	An optimal PMU placement algorithm has been developed to identify where the PMUs have the greatest impact on the accuracy of the state estimation. In addition, a feeder with 3 advanced meters that have a resolution of seconds was selected.
GR.05	Low engagement of small and medium prosumers in the flexibility market. Motivation to participating may stem from lack of financial incentives from the DSO,	User-related	Medium / High	High	Awareness campaigns via digital and traditional media will highlight the benefits of flexibility for grid stability and sustainability. Engagement is strengthened through

	complex rules, technical demands, and misaligned mechanisms. Insufficient participation would limit available flexibility, hinder demonstration activities, and reduce the scalability of the market concept.				targeted communication, surveys, and interactive content (tutorials, case studies, demonstrations). A hub will also support prosumers in monitoring and controlling their energy use, making participation easier and more attractive. As a fallback, participating FSPs will emulate flexibility volumes. This will enable the validation of the TSO-DSO coordination process and tools, despite the lack of real-life market activations.
GR.06	Participant fatigue: repeated tasks without visible benefits may reduce motivation. Large-scale disengagement would jeopardize the reliability and long-term success of the flexibility market.	User-related	Low	Low	A long-term engagement strategy will combine evolving incentives and clear feedback activities. Rewards will be updated based on user input, while personalized progress reports will show impacts on savings, emissions, and grid stability. Gamification, educational content, and mobile app updates could further maintain interest and strengthen user connection to the project.
GR.07	Lack of trust in the flexibility market, especially for prosumers unfamiliar with energy regulations, who may question data privacy, payment reliability, or transparency. If perceived as serving mainly large corporations or unclear in data use, users may hesitate to participate.	User-related	Medium	Low	A transparent and user-centric communication of market goals, participant roles, and prosumer benefits will be ensured through accessible documentation and videos. A communication initiative for the Greek pilot has been established, based on a mailing list. Registered users receive informational interactive materials on the pilot's technologies. The initial outreach has been completed, and additional activities are planned for the near future to further strengthen confidence. Data privacy, consumer rights, and fair benefit sharing will be protected through GDPR and Greek law compliance, clear participation and data management policies, and regular user updates on data use.
GR.08	Engagement may be reduced due to the digital divide (e.g. rural, low-income, older citizens). This inequality could exclude large groups from the flexibility market, reducing participation and overall impact.	User-related	Medium	Low	In the questionnaires, relevant information will be gathered about the users, and analytical guidelines will be provided for using the tools. Simplifying the technology interface is crucial for bridging the gap.
GR.09	The absence of a robust regulatory framework for flexibility markets at the distribution level in Greece, this could hinder post-project deployment and long-term utilization of the developed technologies.	Exploitation risk	Medium / High	Medium	HEDNO and IPTO will engage regulatory authorities with project results and operational insights, aiming to shape legislation that supports flexibility markets at both DSO and TSO levels.

GR.10	Complex regulations, limited incentives, and possible restrictions on the energy trading platform may delay or prevent prosumer engagement.	User-related	Medium	Medium	Measures to protect prosumers from high wholesale electricity prices through fair pricing mechanisms and anti-market manipulation measures are necessary, but not at the cost of discouraging their engagement and flexibility.

4 Swiss pilot site

4.1 Pilot site characterization

4.1.1 Pilot site description

4.1.1.1 General introduction

The Swiss pilot site, originally called Motta District, consisted of a suburban Energy Community (EC). During the first months of the project, following the requirements analysis and a more detailed definition of the use cases, a restructuring of the pilot became necessary. Currently, the Swiss pilot is no longer identified solely with the energy community, but rather includes all users supplied by the same secondary substation, i.e. a single transformer (16/0.4 kV). More details on the structure of the pilot, which is now recognised in the new acronym ECM, are provided in the following sections.
The pilot site is located in Via Motta in the city of Massagno, situated near Lugano in Canton Ticino, Switzerland (Figure 4). The Azienda Elettrica di Massagno (AEM) SA, in addition to operating as the Distribution System Operator (DSO) and energy provider for the municipalities of Massagno, Capriasca, and Isone, is also directly responsible for managing the pilot.

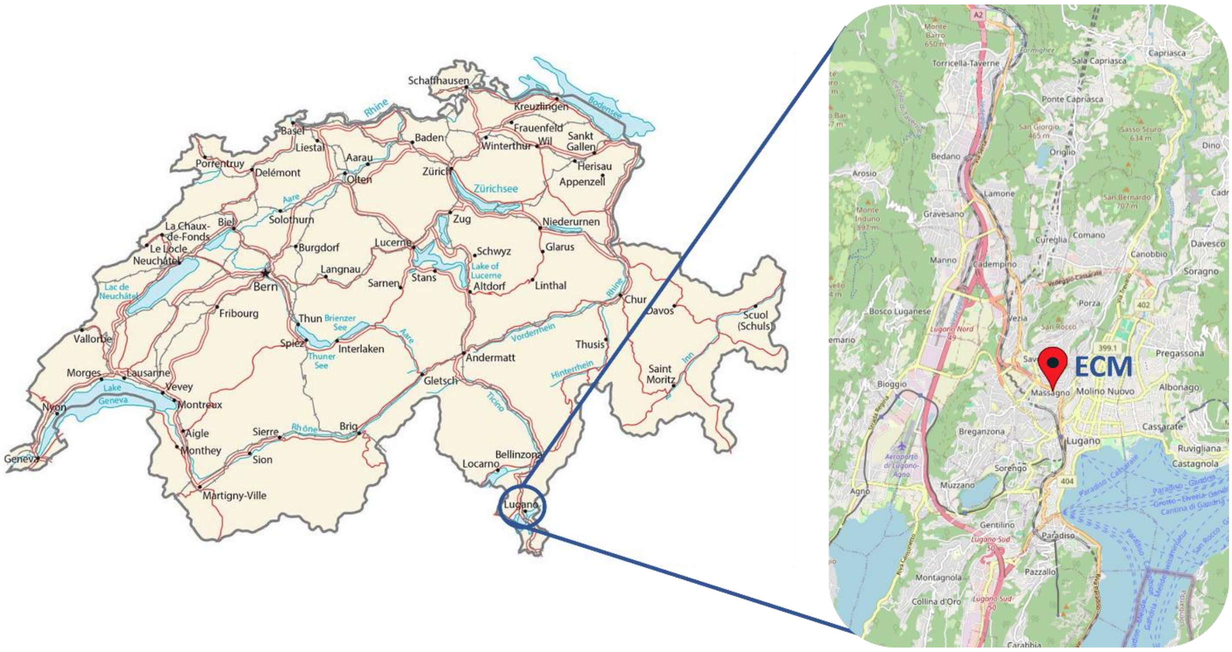


Figure 4. Geographical position of the pilot site (ECM)

4.1.1.2 Main objectives

The primary objective of ECM is to analyse and assess the potential impact of aggregating local energy flexibility to deliver services directly to the distribution network at the low-voltage feeder level. AEM is particularly interested in utilizing this flexibility for peak shaving. Through the aggregation and activation of locally available flexibility, it aims to validate the concept and methodology for mitigating the two typical daily power peaks (i.e., early morning and late afternoon). Reducing these peaks provides dual benefits: economically, for end-users subject to AEM's power tariff (where charges are based on the highest peak recorded within a month), and operationally, enabling the operator to increase grid efficiency and potentially defer costly network investments by scaling the solution up to the entire grid.

During the early stages of the OPENTUNITY project, following several discussions with the technical partners responsible for technology development, AEM identified and selected a set of "horizontal" use cases to support the development of specific services and technologies. An overview of these use cases is outlined in the Deliverable 2.1, along with two pilot-specific use cases. Their aim is to analyse and demonstrate the services that could be provided by small-scale flexibility, considering a minimum capacity of 1 kW, and investigating the coordination and integration of a local flexibility market solution.

Given the different operational and technical implications of real asset activation and the necessity to test the market solution with more than one FSP, two separate lists have been created: one identifying asset that can be both monitored and controlled, and another listing assets that will be modelled and simulated. The two lists will be managed by two different FSPs run by SUPSI.

4.1.1.3 Existing infrastructure

Figure 5 shows a general overview of the network fed by the transformer that defines the pilot. The actual site includes the MV/LV transformer, the feeder supplying the two distribution cabinets highlighted in the figure, and all the Point of Deliveries (PODs) and flexibility resources related to them. The remaining feeders are not in the scope of the studies that will be conducted in the project and are included only for completeness regarding data monitoring; for this reason, only aggregated smart meter data will be provided for this group.

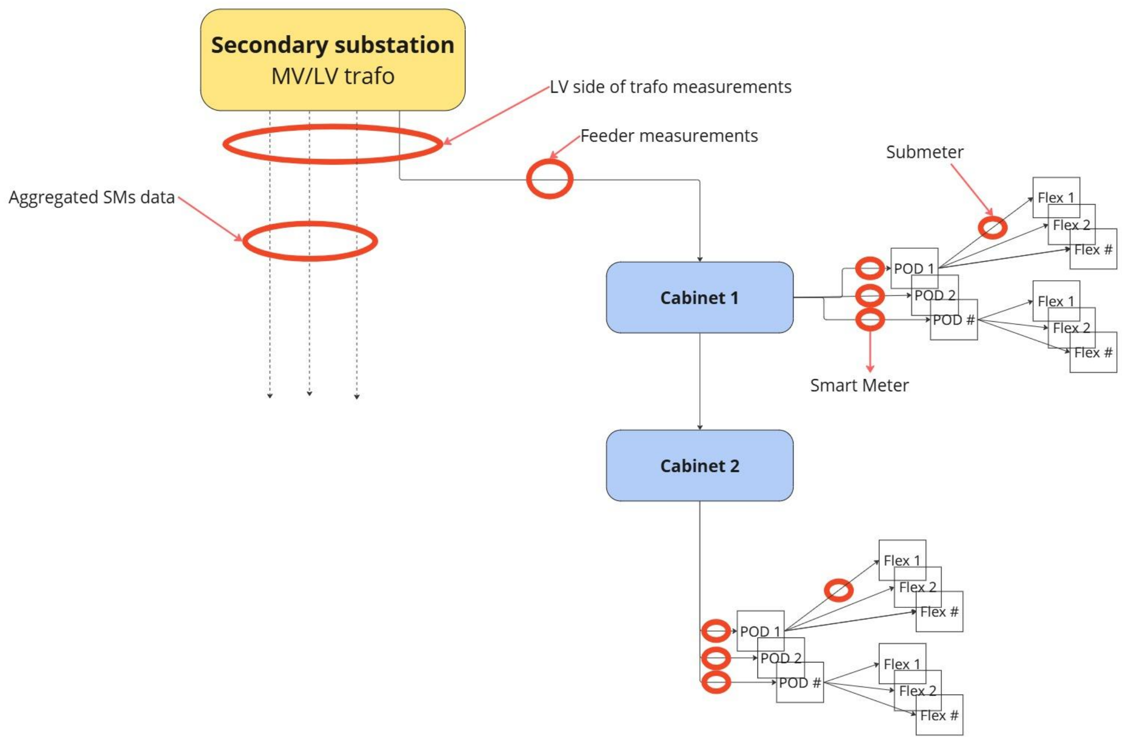


Figure 5. Overview and measurement of the Swiss pilot

Following the structure of the figure above, the red markers indicate the planned measurement points for the final configuration of the pilot. The entire low-voltage network supplies all the connected buildings through a three-phase system down to each individual customer. Starting from the top of it, a grid meter (i.e., SGIM), equipped with two separate channels, is installed to measure both the secondary side of the transformer and the feeder of the pilot. As previously mentioned, for the other feeders, smart meter data will be aggregated into a unique profile, whereas for the feeder on the right, individual anonymized customer data will be provided. Asset level data will be available for a selection of relevant flexibilities thanks to the planned submeter installations.

As shown in Table 4.1, local electricity generation within the pilot is provided by two photovoltaic systems, while heating and domestic hot water are mainly produced using heat pumps and electric boilers and the local electric mobility is supported by two public charging points.

Table 4.1. List of assets in the Swiss pilot

Type	Quantity	Category and electrical rated power
PV	2	Commercial/Services: 60 kW Residential: 10 kW
Heat pump	8	Commercial/Services: 9 kW, 9 kW, 18 kW, 15 kW, 15 kW, 2 kW Residential: 6 kW, 8.4 kW
Water chiller	2	Commercial/Services: 5 kW, 5 kW
Electric boiler	11	Residential: 1.5 kW, 1.5 kW, 1.5 kW, 6 kW, 2 kW, 8.6 kW Commercial/Services: 10 kW, 1 kW, 1 kW, 1 kW, 2.4 kW
EV charger	3	Public: 11 kW, 11 kW Private: 11 kW

4.1.1.4 Data

Various types of data are collected from the pilot site, from the network level down to the asset level. All sensors and meters communicate using different protocols with a dedicated server managed by AEM R&D, where all data is managed anonymously. Project partners can access this data using a single REST API provided by AEM with the technical support of Hive Powe. The API is shared with the relevant documentation and list of endpoints.

For smart meters, AEM relies on its Advanced Metering Infrastructure (AMI), which gathers data sampled every 15 minutes through PLC, radio, and fibre-optic communication. These data are read every 6 hours (on avg.) and stored on servers containing up to four years of historical records. The remaining sensors, namely, the submeters and the grid meter, store historical data starting from their installation date, and provide real-time updates with a frequency of one minute.

Further details are provided in Table 4.2, which lists the available data per sensor type, historical coverage, data acquisition frequencies, and the total number of sensors expected by the end of the deployment phase.

Table 4.2. Sensors and data information

Location	Quantity	Sensor	Monitoring parameters
Point of delivery (POD)	163 + 1 for aggregated feeders	Smart Meter Landis+ Gyr	Import power and export power (kW) for net metering Sampling frequency: 15 min Reading frequency: 6h (on average)
MV/LV transformer	1 (Channel 1 and Channel 2)	Be-energy SGIM	V, P, I RMS, PF for each channel for each phase Sampling frequency: 1 min

			Reading frequency: real-time
Asset level	10 (planned)	Submeter Shelly 3EM PRO	V, I, P, Q, F, PF for each phase Sampling frequency: 1 min Reading frequency: real-time
Selected rooms	10 (planned)	Shelly H&T	Temperature (°C) and relative humidity (RH%) Sampling frequency: 5 min (even base) Reading frequency: real-time

4.1.2 Pilot site roles

Table 4.3. CH pilot site roles

Partner	Role in the demo	Main responsibilities
AEM	Pilot leader, DSO, energy provider	• Pilot surveys • Pilot deployment activities • Pilot coordination activities (UCs, TCs, KPIs, business models, installations, IoT) • Grid, building and asset monitoring • Selected asset controllability • Communication with the stakeholders and end-users
SUPSI	Technical partner	• Pilot technical support • Aggregator and Flexibility Service Provider (FSP) for the local flexibility market
HIVE	Technical partner	• Support in data management platform • Data sharing (REST API)
HYP	Technical partner	• Baseline forecasting • Flexibility forecasting • Control signal generation
NODES	Market operator	• Provide partners access to the NODES platform • Design the market solution and guide the pilot leader during the use case definition and testing procedures
ETRA	Technical partner	• Grid analysis (power flow and state estimation analysis) • Load profile disaggregation (NILM algorithm) • Grid topology analysis

4.1.3 Installed and planned equipment overview

Table 4.4. CH pilot equipment overview

Equipment type	Description	Location	Installation status	Purpose
Grid meter	SGIM is a device from Be-energy (Hager) to monitor in real time the status of the power flow (P, Q, V, I, PF) for each phase. It is equipped with two or more channels to measure with the	Pilot site secondary substation (MV/LV transformer)	Completed	Channel 1 monitor the entire LV side of the transformer, while Channel 2 the feeder that supply the pilot site. It is mainly used to monitor the power flow and the power peaks at the SS

	same device different feeders			
Submeters	Shelly 3EM Pro devices to monitor the single asset electrical parameters (P, Q, V, I, PF) for each phase.	Assets in the flexibility market where control and activations will be conducted	Completed	Monitor the asset demand and the activations requested in the flexibility market
Gateways	Devices from elco company to read and control remotely their heat pumps	Connected to the heat pumps in the buildings managed by the local municipality.	Completed	Devices were already installed, during the project AEM completed the setup, data ingestion and control testing
EV charger managing platform	Dedicated platform to manage public EV charging infrastructure	-	Completed	The platform has been deployed and tested during the project and will be used on the field-level in AEM to control the public EV charging station in the pilot site
Data management platform and REST API	Dedicated platform developed with the support of HIVE POWER technical partner to collect and store data from all the assets and sensors in the pilot site	-	Completed	Read and store data from the assets. Grant external partners access to anonymised data from the pilot site and enable them to perform asset control via a single REST API

4.1.4 Feedback collection plan

Feedback in the Swiss pilot will be collected from two main sources: end-users interacting with the NILM tool, the local municipality indirectly involved in the LFM and internal project partners involved in the demonstrations. The objective is to assess both the user-facing impact of OPENTUNITY innovations and the internal technical/organizational aspects of the demonstrations.

End-user and stakeholder feedback

The NILM technology developed during the project is intended exclusively for residential users. During the project, AEM analysed the Swiss regulatory framework to ensure meter data readings were used in full compliance with existing privacy laws. Unlike activities involving buildings managed by the Municipality of Massagno, engaging with residential users alone proved more challenging. It was difficult to find end users within the pilot site who were willing to test the NILM solution. To avoid missing the opportunity to test the NILM technology, which is of particular interest to AEM, a nearby customer who is already known to be interested in energy innovation was contacted.

While a single user cannot provide statistically significant results, testing the solution remains valuable for AEM as it enables them to gather feedback from a user within their service area and gain insights from someone open to innovation.

Following the request, the user – who resides in an apartment in Massagno – signed an agreement with AEM allowing the DSO to read minute-by-minute data from their smart meter for the purpose of testing the solution.

Before running the test, the end-user was interviewed to investigate their interest and expectations, and a second interview is planned for when the NILM results are available. Disaggregated appliance-level consumption data and efficiency labels will be provided to the customer, and feedback will be collected to evaluate the solution.

- Usability and readability of the tool interface,
- Perceived accuracy of disaggregation results,
- Overall satisfaction and value of the service,
- Broader views on flexibility.

Table 4.5. CH pilot end-user feedback collection plan

What will be collected	Who is involved	Method	Frequency	Use of input
Satisfaction with NILM tool features	Selected customer	Interview	Before and after the test	Improve tool design, refine algorithms, inform WP7 evaluation of user trust and replicability
Flexibility-related views	Selected customer	Interview	Before and after the test	Identify barriers and motivations for current and future flexibility engagement

Internal partner feedback

Municipality LFM test

Thanks to the activities that will be conducted to monitor and control the heat pumps in buildings managed by the Municipality of Massagno, AEM will have the opportunity to interview the technical person responsible for operating the heating systems and to get in contact with the head of the municipality technical office. Expectations, feedback and opinions on flexibility management will be collected before and after the test. Comfort in the buildings will be checked to ensure that the control actions have not been invasive. The results will be presented to demonstrate the potential benefits of flexibility services and local flexibility markets for high-efficiency buildings, despite the significant initial investment required for these systems.

DSO team feedback

During the testing phases, once the tests have been completed and the results are ready to be presented. The AEM R&D team will share them with the DSO operational team for objective and constructive feedback on the benefits and areas for improvement of the tools and services developed by the OPENTUNITY solution.

Table 4.6. CH pilot internal feedback collection plan

What will be collected	Who is involved	Methods	Frequency	Use of input

Data pipeline reliability (SCADA, AMI, submeters)	AEM R&D, SUPSI, HYP	Bilateral meetings	Twice a week during data pipeline configuration and then as needed	Ensure data robustness, continuous flow, and troubleshoot potential errors
Feedback from the municipality technical office	AEM R&D	Bilateral meetings	Pre and post validation	Gather feedback on the potential future implementation of such technologies in other buildings, and collect relevant insights from the building owner's perspective
Feedback from the DSO	AEM R&D AEM DSO	Bilateral meetings	Pre and post validation	Gather feedback on the potential future implementation of such technologies, analyse grid benefits and collect relevant insights from grid experts

4.1.5 User scenario assumptions and impacts

End-users interactions in the Swiss pilot site will be limited to the end-user where the NILM solution will be tested and indirectly to the municipality, that is not actively involved in the project but rather plays a spectator role in the LFM waiting the results from the test that will be conducted to better understand the potential benefits of flexibility management and flexibility markets. The preliminary interview with the end-user where the NILM will be tested highlighted its interests in being more informed on the actual behaviour of the different appliances with the main scope to identify possible ways to increase saving on the electricity bill and from a general perspective contribute to innovative studies that could have significant future impacts in the efficiency of the energy sector.
The preliminary interview has yet to be arranged. AEM is currently liaising with the technical office to arrange a suitable date. From the outset of the installation process, the technical office has expressed an interest in finding solutions to reduce amortisation on investments in heat pump systems and to use flexibility to optimally manage the system in response to grid tariffs, with the aim of reducing electricity and gas bills. Gas bills should be considered for both buildings, as heat pumps are coupled with gas boilers that are used to cover peak demand.

Table 4.7. CH pilot user scenarios

Innovation /tool	Scenario description	Assumptions made	Expected effect if assumptions not met
NILM	Once the NILM analysis is completed, end-users will be able to review the disaggregated consumption profiles to verify their accuracy and assess their potential relevance for future applications.	(1) It is expected the NILM to disaggregate the consumption profile. (2) The end user to write down the times where the main relevant assets are used for the day of the tests (3) 1 min data available from the Smart Meter	(1) The use case cannot be tested (2) Results are not directly comparable and valuable insights cannot be identified. (3) The use case cannot be tested
LFM	Stakeholders like the municipality are playing an indirect role in the use case. Results will be presented after the validation of the solution.	(1) Presence of controllable assets (2) data and control signals integrated in the API (3) Data integrated in the NODES platform	All assumptions are necessary to guarantee the validation of the use case.

4.2 Deployment plan

Table 4.8. CH pilot deployment plan. The dashed red line represents the start of OPENTUNITY demonstrations.

Swiss pilot site deployment	2023				2024				2025											
	Jan - Sep	Oct	Nov	Dec	Jan	Feb	Mar-Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	M01-M09	M10	M11	M12	M13	M14	M15-M23	M24	M25	M26	M27	M28	M29	M30	M31	M32	M33	M34	M35	M36
Preliminary building on-site inspections																				
Internal analysis and integration of new pilot buildings																				
Secondary set of building on-site inspections + internal analysis (focused on verify the requirements for asset monitoring and control)																				
Discuss authorizations with the end-users (monitoring and control)																				
Purchase the equipment and sensors (submeters, routers, gateways)																				
Equipment and sensors installations																				
[Monitoring] devices ingestion (submeters and sensors)																				
[Monitoring] devices API developments (submeters and sensors)																				
[Control] devices ingestion (gateways and AMI)																				
[Control] devices API developments (gateways and AMI)																				
[Control] internal tests																				
[Grid] device installation (LV transformer and feeder)																				
[Grid] device ingestion																				
[Grid] API developments																				

4.3 Test cases, datasets and KPIs

This section provides a structured summary of the test cases, datasets, and KPIs associated with the pilot site. Full versions of the filled-in templates (test case, dataset, KPI) will be included in the annex. This section provides an overview and mapping only.

4.3.1 Test cases

In the Swiss pilot, 11 test cases will be demonstrated, their short descriptions are provided below and the full descriptions are included in Annex 1 (section 10.1.2).

Table 4.9. Summary of CH pilot's test cases

Category	Test case ID	Test case name
Horizontal	TC1.1.2	Voltage variation forecast (CH pilot)
	TC1.2.2	NILM identification ability (CH pilot)
	TC1.3.2	State estimation accuracy (CH pilot)
	TC1.6.1	Topology identification ability (CH pilot)
	TC1.8.1.3	Baseline consumption forecast (CH pilot)
	TC1.8.2.3	Flexibility consumption forecast (CH pilot)
	TC1.8.3.3	Dispatch of control signals to assets (CH pilot)
	TC1.9.2	Registration of consumers' preferences (CH pilot)
	TC1.10.3	Peak shaving using local assets (CH pilot)
Pilot-specific	TC5.1.1	Flexible asset management for peak reduction at the secondary substation
	TC5.2.1	Local flexibility market between the local DSO and two FSPs

TC1.1.2 Voltage variation forecast (CH pilot)

Short description: this test case will analyze the precision of the voltage variation forecast performed in ÉTER and will also check if the voltage variations are within the thresholds defined by the DSO

Main responsible partners:

- AEM - Grid operator providing historical and real-time data
- ETRA - ÉTER technology provider, with a functionality to analyze the short-term impact of DER in the grid

Involved assets & systems:

- ÉTER
- AEM grid meters (P, Q, V, I)
- AEM AMI (exported and imported power)
- Weather forecast provider (Open Weather)

Environment: Live

TC1.2.2 NILM identification ability (CH pilot)

Short description: the goal of this test case is to analyze the ability of the NILM module to identify the different appliances of one residential customer using just the real time smart meter data as an input

Main responsible partners:

- AEM - Smart meter data 1 min (imported power)
- ETRA - NILM developer

Involved assets & systems:

- Smart meter
- Customer manual records (main asset activations)
- NILM module

Environment: Live

TC1.3.2 State estimation accuracy (CH pilot)

Short description: the target is to increase DSO grid observability, especially in LV networks

Main responsible partners:

- AEM - Grid operator providing historical and real-time data
- ETRA - ÉTER technology provider, with a functionality to perform state estimation

Involved assets & systems:

- ÉTER (which includes the topology of the grid)
- Grid meter (P, Q, V, I)
- AMI (P; and Q, V and I if possible) [1]
- Weather forecast provider (Open Weather)
- Topology model of the grid (ETER and AEM data)

Environment: Live

TC1.6.1 Topology identification ability (CH pilot)

Short description: the target is to automatically identify grid topology and line parameters using historical grid and smart meter data. By analyzing voltage and power correlations, the module reconstructs network connections and impedance values, comparing them with known configurations to validate identification accuracy.

Main responsible partners:

- AEM - Grid operator providing historical and real-time data
- ETRA - ÉTER technology provider, with a functionality to identify topology

Involved assets & systems:

- Grid meter (P, Q, V, I)
- AMI system (P; and Q, V and I if possible) [2]
- ÉTER (which includes a topology identification module)
- Incomplete topology model of the grid (AEM)

Environment: Live

TC1.8.1.3 Baseline consumption forecast (CH pilot)

Short description: this test case evaluates the BFMS in its ability to forecast baseline electricity consumption for pilot assets. The BFMS is trained and validated using historical and real-time data

[1] There are discussion currently ongoing between ETRA and AEM to check the legal aspect of data sharing (Q, V, I).

[2] Same as above.

from the EMS and data space to generate accurate daily baseline predictions for subsequent flexibility analyses

Main responsible partners:

- HYP – BFMS responsible partner
- AEM – Asset operator at the Swiss pilot
- QUE – Data Space operator

Involved assets & systems:

- Assets at pilot sites, including EMS
- BFMS
- Data Space (Data Space connector deployed at each participant site)

Environment: Live

TC1.8.2.3 Flexibility consumption forecast (CH pilot)

Short description: this test case evaluates the capability of the BFMS to forecast DR flexibility consumption for pilot assets. The system is trained using real consumption data to predict both baseline and flexible load profiles, thereby quantifying available flexibility and supporting the optimization of DR events at the pilot site

Main responsible partners:

- HYP – BFMS responsible partner
- AEM – Asset operator at the Swiss pilot
- QUE – Data Space operator

Involved assets & systems:

- Assets at pilot sites, including EMS
- BFMS
- Data space (Data Space connector deployed at each participant site)

Environment: Live

TC1.8.3.3 Dispatch of control signals to assets (CH pilot)

Short description: this test case demonstrates the solution ability to automatically dispatch control signals from the BFMS to controllable assets at the Swiss pilot site. After validated flexibility orders have been issued on the NODES platform, the BFMS sends control commands to local assets via the AEM Data Space. The aim is to verify the correct communication, activation and response of the assets during real flexibility events

Main responsible partners:

- HYP – BFMS responsible partner
- AEM – Asset operator at the Swiss pilot
- NODES – NODES platform operator
- QUE – Data Space operator

Involved assets & systems:

- BFMS
- Data space (Data Space connector deployed at each participant site)
- NODES platform
- Assets at pilot sites, including EMS

Environment: Live

TC1.9.2 Registration of consumers' preferences (CH pilot)

Short description: this test case focuses on collecting and managing consumers' preferences for each controllable asset within the Swiss pilot site. Through the DR initialization interface, users can set their own comfort or operational preferences, which are then sent to and stored in the BFMS. The aim is to integrate these settings into flexibility optimization algorithms to ensure personalized, user-centric demand response actions

Main responsible partners:

- HYP – BFMS responsible partner
- AEM – Asset operator at the Swiss pilot
- QUE – Data Space operator

Involved assets & systems:

- Assets at pilot sites, including EMS
- BFMS
- Data space (Data Space connector deployed at each participant site)

Environment: Live

TC1.10.3 Peak shaving using local assets (CH pilot)

Short description: This test case, related to the LFM for the Swiss pilot site, aims to test and validate the final market integration. The full data pipeline will be verified to ensure proper interaction between the FSP and DSO bidding algorithms and the NODES platform. API integrations between the partners responsible for metering data and those managing the EMS will also be tested. Finally, initial asset control tests will be carried out on EV charging stations and heat pumps. Planned activities include verifying baseline forecasts, activation accuracy, and local flexibility performance before launching the final market test in TC5.2.1.

Main responsible partners:

- HYP (BFMS responsible partner)
- NODES (platform operator)
- AEM (pilot manager)
- AEM (DSO)
- SUPSI (FSP)

Involved assets & systems:

- AEM AMI
- AEM submeter data
- NODES platform
- HYP BFMS tool
- AEM/SUPSI bids and offers automatic submissions scripts
- AEM EV charging stations, heat pumps and electric boilers in the pilot

Environment: Live

TC5.1.1 Flexible asset management for peak reduction at the secondary substation

Short description: the objective of this test case is to validate the control and coordination of small flexible assets (e.g. heat pumps, electric vehicle chargers and electric boilers) to reduce daily load peaks at the secondary substation. Demand and available flexibility forecasts are used to identify peak periods, aggregate flexible capacity through the FSP and activate assets accordingly. Performance is monitored at both grid and asset levels for KPI validation

Main responsible partners:

- AEM (DSO)
- AEM (pilot manager)
- HYP (EMS, forecaster)
- SUPSI (FSP, virtual FSP, provider of simulated data for not-submetered assets)
- HPOW (data tech support)

Involved assets & systems:

- Assets from the pilot: heat pumps, EV chargers, electric boilers
- AEM Advanced Metering Infrastructure (AMI)
- AEM grid meters, submeters and temperature and humidity sensors
- AEM control gateways
- AEM's EV charger platform
- AEM R&D server (database)
- HYP forecasters (demand, production, flexibility)

Environment: Hybrid – The use case includes two groups of assets: one with active control and a second with emulated activations.

TC5.2.1 Local flexibility market between the local DSO and two FSPs

Short description: this test case illustrates a local flexibility market in which the DSO and two FSPs exchange flexibility via the NODES platform. Demand and flexibility forecasts are used to identify requirements and offers, which are then matched through automated bidding and clearing. This process validates technical integration and market operation, as well as the benefits of aggregating DERs under a secondary substation

Main responsible partners:

- AEM (DSO)
- AEM (pilot manager)
- HYP (EMS, forecaster)
- SUPSI (FSP, virtual FSP, provider of simulated data for not-submetered assets)
- HPOW (data tech support)
- NODES (FMO)

Involved assets & systems:

- Assets from the pilot: heat pumps, EV chargers, electric boilers
- AEM AMI
- AEM grid meters, submeters and temperature and humidity sensors
- AEM control gateways
- AEM's EV charger platform
- AEM R&D server (database)
- HYP forecasters (demand, production, flexibility)
- NODES market platform

Environment: Hybrid – The use case includes two groups of assets: one with active control and a second with emulated activations

4.3.2 Datasets

Table 4.10. Datasets provided by CH pilot for test cases

Dataset ID	Dataset name
DS.CH.01	Baseline per portfolio
DS.CH.02	Metering data/Smart meters
DS.CH.03	Grid infrastructure – high level information
DS.CH.04	Asset data
DS.CH.05	Smart meter (single POD for NILM)
DS.CH.06	Grid topology
DS.CH.07	Weather data
DS.CH.08	Indoor temperature and humidity
DS.CH.09	Grid meter
DS.CH.10	Consumers' preferences per asset
DS.CH.11	Control signals to assets at pilot sites
DS.CH.12	Asset flexibility power consumption forecast
DS.CH.13	Asset power consumption
DS.CH.14	Asset baseline power consumption forecast

Table 4.11. CH pilot mapping datasets with test cases

		Test cases										
		1.1.2	**1.2.2**	**1.3.2**	**1.6.1**	**1.8.1.3**	**1.8.2.3**	**1.8.3.3**	**1.9.2**	**1.10.3**	**5.1.1**	**5.2.1**
Datasets	**DS.CH.01**									■		
	DS.CH.02	■		■	■					■	■	■
	DS.CH.03									■		
	DS.CH.04									■	■	■
	DS.CH.05		■									
	DS.CH.06			■	■							
	DS.CH.07	■		■								
	DS.CH.08										■	
	DS.CH.09	■		■	■						■	■
	DS.CH.10								■			
	DS.CH.11							■				
	DS.CH.12						■					
	DS.CH.13					■						
	DS.CH.14					■						

4.3.3 KPIs

4.3.3.1 Summary and mapping of CH pilot KPIs

Table 4.12. Summary of CH pilot's KPIs

New KPI ID	Old KPI ID	Title	Action	Comment
KPI.SE.01	KPI_01	Variability of the voltage	Kept	-
KPI.NILM.01	KPI_02	NILM F1	Kept	-
KPI.SE.02	KPI_03	State estimation MAPE	Updated	Renamed and adapted to SE

KPI.TI.01	KPI_07	Topology identification MAPE	Updated	Changed metric from F1 score to MAPE
KPI.HEMS.01	KPI_10	Demand forecasting accuracy	Kept	-
KPI.HEMS.02	KPI_11	Flexibility delivery precision	Kept	-
KPI.HEMS.03	KPI_12	Flexibility potential	Kept	-
KPI.HEMS.04	KPI_13	GHG reduction	Kept	-
KPI.HEMS.05	KPI_14	Load reduction/increase	Kept	-
KPI.HEMS.06	KPI_15	Rate of successful DR events	Kept	-
KPI.HEMS.07	KPI_16	Thermal comfort violation	Updated	More accurate representation of thermal comfort
-	KPI_17	Local average voltage deviation index	Removed	Not applicable in the Swiss pilot
-	KPI_20	TSO-DSO coordination efficiency	Removed	Not applicable in the Swiss pilot
KPI.FM.03	KPI_21	Potential offered flexibility	Kept	-
KPI.FM.04	KPI_22	Type of flexibility providers	Kept	-
-	KPI_23	Accuracy on assets flexibility	Removed	Similar to KPI.HEMS.02
KPI.CH.01	KPI_44	Average amount of flexibility available from the energy community	Kept	-
KPI.CH.02	KPI_45	Average peak load reduction at the MV/LV transformer station	Kept	-
KPI.CH.03	KPI_46	Error in the prediction of electricity demand	Kept	-
KPI.CH.04	KPI_47	Error in the prediction of photovoltaic production	Kept	-
KPI.CH.05	KPI_48	Flexibility activation accuracy	Kept	-
KPI.CH.06	KPI_49	Max flexibility prediction accuracy	Kept	-

Table 4.13. CH pilot mapping KPIs with test cases

		Test cases										
KPIs		1.1.2	1.2.2	1.3.2	1.6.1	1.8.1.3	1.8.2.3	1.8.3.3	1.9.2	1.10.3	5.1.1	5.2.1
	KPI.SE.01	X										
	KPI.NILM.01		X									
	KPI.SE.02			X								
	KPI.TI.01				X							
	KPI.HEMS.01					X						
	KPI.HEMS.02							X		X		
	KPI.HEMS.03					X	X			X		
	KPI.HEMS.04						X	X				
	KPI.HEMS.05						X	X				
	KPI.HEMS.06							X				
	KPI.HEMS.07								X			
	KPI.FM.03									X		
	KPI.FM.04									X		
	KPI.CH.01											X
	KPI.CH.02										X	
	KPI.CH.03										X	
	KPI.CH.04										X	
	KPI.CH.05											X
	KPI.CH.06										X	X

Table 4.14. CH pilot mapping KPIs with strategic objectives

Strategic objectives	KPIs →	KPI.SE.01	KPI.NILM.01	KPI.SE.02	KPI.TI.01	KPI.HEMS.01	KPI.HEMS.02	KPI.HEMS.03	KPI.HEMS.04	KPI.HEMS.05	KPI.HEMS.06	KPI.HEMS.07	KPI.FM.03	KPI.FM.04	KPI.CH.01	KPI.CH.02	KPI.CH.03	KPI.CH.04	KPI.CH.05	KPI.CH.06
	SO1. Decarbonization of EU society	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

4.3.3.2 Pilot site baseline overview

Each KPI related to the Swiss pilot needs to be calculated after demonstrations and benchmarked with state-of-the art or business as usual (BAU) figures. We present here the baseline methodology selected for each KPI, with its value (or expected value) marked in **orange**. When OPENTUNITY innovation tools are expected to bring a relevant improvement, we also argue for our estimated target, marked in **red**.

KPI.SE.01 Variability of the voltage

± 10% is the maximum voltage variation allowed (during 95% of the time) in according to UNE 50.160. This figure will serve as a reference value for this KPI. This value will serve as a baseline value, ensuring that this value is respected during the test, and trying to reach an even lower figure of **± 5%**.

KPI.NILM.01 NILM F1

Currently, there is no method for disaggregating energy consumption data in place in the pilots, so the project is providing a new service that opens the door to new impacts. Considering this value and to further improve the performance, the baseline for OPENTUNITY has been set to **80%** but for F1-score, which considers the accuracy, precision and recall of the classes to predict (ON and OFF detections). The project aims to increase this value to **at least 85% on average**, considering the F1-score of each one of the appliances monitored.

KPI.SE.02 State estimation MAPE

The performance of state estimation algorithms depends on the observability of the grid and the real measurements available. However, research estimates the errors as follows:

- **Voltage: ±2%**
- **Angle: ±5%**
- **Power flows: ±10%**
- **Loads: ±10%**

OPENTUNITY techniques are expected to leverage Physic Informed Neural Networks (PINNs) to ensure keeping the MAPE lower than these thresholds (the target is to **lower them about 50%**).

KPI.TI.01 Topology identification MAPE

There is currently no topology detection algorithm deployed in any pilot to compare with (so we set it at 0). Nevertheless, state-of-the-art in the field accounts for an accuracy of **60%**. Our goal is to enhance this level but calculating the MAPE, being or target MAPE **<40%**.

KPI.HEMS.01 Demand forecasting accuracy

As described in D2.1, this KPI is calculated using the following formula:

$$MAE_{forecast} = \frac{\sum_{t=1}^{T} |P_{act,t} - P_{b,t}|}{T}$$

Where:

- $MAE_{forecast}$: mean absolute error between the actual and the forecasted demand (baseline power consumption), 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 ($t \in 1, \ldots, T$)

To calculate the baseline value for this KPI, one should consider that the tool (BFMS) is not applied. In the absence of the BFMS, the baseline power consumption is considered equal to the power consumption of the previous day. The KPI is then calculated by subtracting the day before power consumption from the actual power consumption for the day of interest and for the same timeframe. **This value changes dynamically every day, based on the asset, the season and the occupant preferences**.

KPI.HEMS.02 Flexibility delivery precision

As described in D2.1, this KPI is calculated using the following formula:

$$FD_{error} = \frac{\sum_{t=1}^{T} |P_{del,t} - P_{bid,t}| \cdot I_t}{\sum_{t=1}^{T} P_{bid,t}} \cdot 100\%$$

Where:

- 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 bid 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 ($t \in 1, \ldots, T$)

To calculate the baseline value for this KPI, one should consider that the tool (BFMS) is not applied. In the absence of the BFMS, the delivered flexibility would be equal to zero. This would result in a **0%** flexibility delivery precision value for the baseline scenario of this KPI.

KPI.HEMS.03 Flexibility potential

As described in D2.1, this KPI is calculated using the following formula:

$$E_{flex} = \sum_{t=1}^{T} (P_{b,t} - P_{opt,t})$$

Where:

- 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 ($t \in 1, \ldots, T$)

To calculate the baseline value for this KPI, one should consider that the tool (BFMS) is not applied. In the absence of the BFMS, the baseline power consumption is considered equal to the power consumption of the previous day; the same assumption applies for the optimized power consumption. This results in a **0 kWh** flexibility potential for the baseline scenario of this KPI.

KPI.HEMS.04 GHG reduction

As described in D2.1, this KPI is calculated using the following formula:

$$GHG_{Reduction} = EF \cdot \sum_{t=1}^{T} (P_{act,t} - P_{DR,t})$$

Where:

- $GHG_{Reduction}$: 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 ($t \in 1, \ldots, T$)

To calculate the baseline value for this KPI, one should consider that the tool (BFMS) is not applied. In the absence of the BFMS, the adjusted power consumption is considered equal to the actual power consumption. This results in a **0 gCO_2eq GHG** reduction for the baseline scenario of this KPI.

KPI.HEMS.05 Load reduction/increase

As described in D2.1, this KPI is calculated using the following formula:

$$E_{change} = \sum_{t=1}^{T} (P_{act,t} - P_{DR,t})$$

Where:

- 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 ($t \in 1, \ldots, T$)

To calculate the baseline value for this KPI, one should consider that the tool (BFMS) is not applied. In the absence of the BFMS, the adjusted power consumption is considered equal to the actual power consumption. This results in a **0 kWh** load reduction/increase for the baseline scenario of this KPI.

KPI.HEMS.06 Rate of successful DR events

As described in D2.1, this KPI is calculated using the following formula:

$$R_{S,DR} = \frac{N_{S,DR}}{N_{total,DR}} \cdot 100\%$$

Where:

- $R_{S,DR}$: rate of successful DR events (percentage)
- $N_{S,DR}$: number of successful DR events
- $N_{total,DR}$: number of total DR requests

To calculate the baseline value for this KPI, one should consider that the tool (BFMS) is not applied. In the absence of the BFMS, the number of successful DR events is considered equal to zero. This results in a **0%** rate of successful DR events for the baseline scenario of this KPI.

KPI.HEMS.07 Thermal comfort violation

A minor modification to this KPI has been made (compared to D2.1) for a more accurate representation of the thermal comfort. For completeness, the KPI is presented in Annex I. Based on the updated version, the KPI calculation formula is as follows:
Where:

$$TC = \sum_{t=1}^{T} (\theta_{limit,l,t} - \theta_{actual,t}) \cdot I_{l,t} \cdot \Delta t + \sum_{t=1}^{T} (\theta_{actual,t} - \theta_{limit,u,t}) \cdot I_{u,t} \cdot \Delta t$$

- 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
- $\theta_{limit,l,t}$: lower temperature limit at time t
- $\theta_{limit,u,t}$: upper temperature limit at time t
- $I_{l,t}$: indicator variable which shows the existence of a lower temperature limit violation at time t (can be either zero or one). 0: above lower limit. 1: below lower limit.
- $I_{u,t}$: indicator variable which shows the existence of an upper temperature limit violation at time t (can be either zero or one). 0: below upper limit. 1: above upper limit.
- t: time index ($t \in 1, \ldots, T$)

To calculate the baseline value for this KPI, one should consider that the tool (BFMS) is not applied. In this case, it can be assumed that the actual temperature is equal to the temperature set by the occupant, which in turn is within the upper and lower temperature limits set by the occupant. This results in a **0°C·h** thermal comfort violation for the baseline scenario of this KPI.

KPI.FM.03 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.
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:

$$Flex_{PO} = \sum_{i=1}^{N} \sum_{t=1}^{T} P.flex_{PO_{i,t}}$$

- $\mathrm{P.flex}_{\mathrm{PO}_{i,t}}$: 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

The baseline is **0 kW** since no flexibility service is currently implemented in the pilot site

KPI.FM.04 Type of flexibility providers

This KPI reflects if and how different types of technologies can be accessed and utilized during the demonstration phase. Since the flexibility management service is being introduced for the first time, no baseline is available for this KPI, we can therefore assume a value of **0%**.

KPI.CH.01 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.

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.

$$\mu_{flex\ t} = \frac{\sum_n^N P_n}{N}$$

$$\mu_{flex\ mean} = \frac{\sum_t^T \mu_{flex\ t}}{T}$$

$$\sigma_{flex} = \sqrt{\frac{\sum_t^T \left(\mu_{flex\ t} - \mu_{flex\ mean}\right)^2}{T}}$$

No baseline is available for this KPI, as the flexibility management service is being introduced for the first time.

KPI.CH.02 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.

$$y_{max} = \max_{t \in \mathcal{T}} y(t)$$

$$y_{max,ctrl} = \max_{t \in \mathcal{T}} y(t) + y_{flex}(t) = \max_t y_{ctrl}(t)$$

$$\mathrm{KPI}_1 = y_{max} - y_{max,ctrl}$$

$$\mathrm{KI}_1 = \Delta t \sum_{t=1}^{T} maximum\left(y(t) - y_{max,ctrl}, 0\right)$$

$$\mathrm{KI}_2 = \mathrm{KI}_1 / \mathrm{KPI}_1 \qquad \text{if } y_{max} > y_{max,ctrl}$$

No baseline is available for this KPI, as the flexibility management service is being introduced for the first time.

KPI.CH.03 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.

$$AFE_{demand} = \frac{\sum_i^I RMSE_{forecasted\ demand\ i}}{I}$$

$$RMSE_{forecatsed\ demand\ i} = \sqrt{\frac{1}{T}\sum_t^T (E\ Actual_t - E\ Forecasted_t)^2}$$

No baseline is available for this KPI, as the forecast service is being introduced for the first time.

KPI.CH.04 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.

$$AFE_{production} = \frac{\sum_i^I RMSE_{forecasted\ demand\ i}}{I}$$

$$RMSE_{forecatsed\ production\ i} = \sqrt{\frac{1}{T}\sum_t^T (E\ Actual_t - E\ Forecasted_t)^2}$$

No baseline is available for this KPI, as the forecast service is being introduced for the first time.

KPI.CH.05 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.

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.

$$MAE = \frac{1}{T}\sum_{t \in T}\left|\frac{y(t) - x(t)}{x(t)}\right| \qquad \mathrm{T}: \{t: n_{activated} > 0\}$$

No baseline is available for this KPI, as the flexibility management service is being introduced for the first time.

KPI.CH.06 Max flexibility prediction accuracy

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.

$$MAE = \frac{1}{T}\sum_{t \in T}\left|\frac{y(t) - x(t)}{x(t)}\right| \qquad \mathrm{T}: \{t: n_{activated} = n_{max}\}$$

No baseline is available for this KPI, as the forecast service is being introduced for the first time.

4.4 Demonstration plan

Table 4.15. CH pilot demonstration plan. The dashed red lines represent the start and end of OPENTUNITY demonstrations.

Swiss pilot demonstration plan		2025				2026								
	Jan 2023 - Aug 2025	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	M01-M32	M33	M34	M35	M36	M37	M38	M39	M40	M41	M42	M43	M44	M45
TC1.1.2 Voltage variation forecast														
Agree on the test conditions and the area of interest				■	■									
Verify data quality and availability before the test						■	■							
Preliminary test								■						
Preliminary results analysis and adjustments									■					
Validation test										■	■	■		
KPI calculations and reporting												■	■	
TC1.2.2 NILM identification ability														
Agree on the test conditions		■	■											
Sign an agreement with the end-user to test the solution		■	■											
Internal tests on the pilot site to check gather 1-min data				■										
Collect historical data (1 month)				■										
First test					■									
Preliminary results analysis and adjustments						■	■	■	■					
Second test										■				
KPI calculations and reporting											■	■		
TC1.3.2 State estimation accuracy														
Agree on the test conditions		■	■											
Verify data quality and availability before the test		■	■											
First test				■	■									
Preliminary results analysis and adjustments						■	■	■						
Second test									■	■				
KPI calculations and reporting											■	■		
TC1.6.1 Topology identification ability														
Agree on the test conditions		■	■											
Verify data quality and availability before the test		■	■											
First test				■	■									
Preliminary results analysis and adjustments						■	■	■						
Second test									■	■				
KPI calculations and reporting											■	■		
TC1.8.1.3 Baseline consumption forecast														
Swiss pilot internal data quality check		■	■											
Complete the installation of T&H sensors		■												
BFMS training				■										

Calculate the BFMS baseline consumption predictions
KPI calculations and reporting
TC1.8.2.3 DR flexibility consumption forecast
Preliminary steps from Test Case 1.8.2
Calculate the BFMS flexibility predictions
KPI calculations and reporting
TC1.8.3.3 Dispatch of control signals to assets
Preliminary steps from Test Case 1.8.4
BFMS receive order accepted from NODES platform
BFMS issues control signals for controllable assets
KPI calculations and reporting
TC1.9.2 Registration of consumers' preferences
Asset owner (consumer) preferences are collected
Preferences are saved on the BFMS
TC1.10.3 Peak shaving using local assets
Market platform full data pipeline test 1 (DSO/FSP bidding algorithms)
Asset control test (active control signals)
Asset simulation (modelling and integration)
Market platform full data pipeline test 2 (activations)
Results analysis and market tuning (preliminary step to TC5.2.1)
TC5.1.1 Flexible asset management for peak reduction at the secondary substation
Asset control internal tests
Control parameters tuning
First validation test
Preliminary results analysis and adjustments
Second validation test
KPI calculations and reporting
TC5.2.1 Local flexibility market between the local DSO and two FSPs
First validation test
Preliminary market results analysis and adjustments
Second validation test
KPI calculations and reporting

4.5 Risk management plan

Table 4.16. CH pilot risk management plan

Risk ID	Risk description	Category	Likelihood	Impact	Mitigation/contingency action
CH.01	Lack of assets with active flexibility control in the LFM	Technical	Medium	High	To ensure a proper market testing environment, AEM expanded the pilot site to include all buildings connected to the same LV feeder. Leveraging its long-standing collaboration with the local municipality, AEM deployed the most promising heat pumps in the area, enabling the testing of asset flexibility control. To assess the impact of a high number of flexibility activations on the feeder, a dedicated tool will be used to model the other assets and simulate their activations in the market.
CH.02	Loss of real-time data reading from submeters or other sensors	Data	Low	High	In addition to having historical data backups available in its R&D database, AEM constantly monitors the status of data transmission using dedicated alarms and algorithms. In case a problem occurs, technical staff is available at short notice to resolve the issue, both from a hardware and software perspective.
CH.03	Deployment delays (installation, data ingestion and API integration)	Organizational	Low	High	The most significant deployment activities have already been completed. At present, the problem could arise with the integration of the APIs of the EV charging station management platform and their control. To mitigate possible problems, we are in constant contact with the platform's technical support and have assigned the integration work to an API expert in the AEM R&D team. Heat pumps can also pose integration problems, which is why AEM initially focused on testing the operation of the assets and the manual availability of data for initial checks. To ensure the functionality of the heat pump control, it was decided to develop a simplified control API that would allow the systems to be switched off or on.
CH.04	Comfort problems due to heat pumps control	User-related	Low	Medium	To avoid problems of this kind, promising systems with water preheating systems have been chosen. In this way, controlling assets even for longer periods does not lead to direct changes in the temperature of buildings or in their domestic hot water production.
CH.05	No participant for the NILM validation	User-related	Low	High	Given the complexity of both the legal aspects and user engagement for this type of technology, AEM relied on a user who is not part of the pilot site but who have a strong interest in innovative technologies. Thanks to the collaboration with this customer, it will be possible to test the tool and obtain relevant feedback for its improvement.

5 Spanish pilot site

5.1 Pilot site characterization

5.1.1 Pilot site description

The Spanish demo site can be divided in three areas:

- a 40kV line between the municipalities of Centelles and Taradell, where the use case regarding Real Time Thermal Rating will be tested
- the municipality of Santa Eulàlia de Ronçana, where all other DSO focused use cases will be tested, along with the client facing use cases
- the municipality of Bigues i Riells, where the client facing use cases will also be tested

The pilot area for the Real Time Thermal Rating innovation consists of a 10km long 40kV line between two primary MV/MV substations. The line is mostly overhead of type LA-110, with a small underground section of around 850m. This line was chosen given the measurements available on its connecting substations, Anell's exploitation plans for its 40kV grid, and data connectivity in the area. The last point is relevant as two sensors will be installed to measure the conductor's temperature, one in each extremity of the line.

The DSO focused use cases which will be tested in the Spanish pilot have the premiss of increasing the DSO's observability of the grid, thus improving its management in the context of an increase in distributed renewable energy sources and in the presence of fraud. Taking this into consideration, the pilot demo ought to be in an area with a significant number of exporters connected to the grid and history of fraud. Santa Eulàlia de Ronçana is amongst the top 5 municipalities in Spain in terms of absolute and relative amount of supply points exporting energy to the grid. Additionally, there have been 100 confirmed cases of fraud registered in Anell's grid over the last four and a half years, 25 of which were in Santa Eulàlia de Ronçana. Only last year there were four cases of confirmed fraud in this municipality. Based on these two criteria, Santa Eulàlia de Ronçana was selected as the primarily municipality for the pilot.

The recent increase in the number of distributed energy resources connected to Anell's grid, which includes solar photovoltaic panels for self-consumption behind the meter and electrical vehicles, increases the voltage volatility in certain regions of the grid and creates new obstacles towards assuring the necessary quality of service. Asking for flexibility in critical moments could help balancing the grid. In order to test this, the local flexibility market ought to be established in an area with significant exportation into the grid. With this in mind, Santa Eulàlia de Ronçana was also chosen as the demo site for the client facing use cases. To be able to reach and invite more clients to participate in the pilot, it was decided to expand the demo site to a second municipality; given its amount of supply points exporting energy to the grid and its interconnections with the grid infrastructure in Santa Eulàlia de Ronçana, the municipality of Bigues i Riells was also chosen.

These two municipalities are quite similar in size and in terms of the grid infrastructure in place. There are two primary substations in Santa Eulàlia de Ronçana and one in Bigues i Riells. Both municipalities have over 40 secondary substations, around 30km of MV lines and around 80km of LV lines. There is a bit over 2800 supply points in each municipality, with 9% and 11% of which are exporting to the grid in Bigues i Riells and Santa Eulàlia de Ronçana, respectively.

5.1.2 Pilot site roles

Table 5.1. SP pilot site roles

Partner	Role in the demo	Main responsibilities
ANELL	Demo leader, DSO	Oversees pilot activities, provides data for testing different innovations, participates in the local flexibility market.
IMPULSA	Energy retailer, Aggregator	Assists Anell in pilot implementation, responsible for participants' engagement and managing their flexibility assets.
ETRA	Main technology provider	Leads some WP5 innovations, such as topology identification and state estimation, WP4 NILM innovation, Grid-EMS and BEMS provider.
ICCS	Technology provider	Leads some WP5 innovations, such as real time thermal rating and advanced asset management.
HYP	Technology provider, FSP	Leads WP4 demand-response optimization innovation, BFMS provider.
NODES	Market operator	Local flexibility market operator.

5.1.3 Installed and planned equipment overview

In the context of the OPENTUNITY project, equipment was and is being installed in Anell's grid and at Estabanell Impulsa client's premises, to enable proper monitoring and control needed for the testing of the innovations. Further information can be found in the table below.
In all cases the data collected is sent to the equipment provider's servers and then made available via their platform or app and via their API. In the case of the devices that also allow for controlling certain appliances, performing actions is also possible via their app or API, thus their API is being used for the integration with OPENTUNITY's innovations.

Table 5.2. SP pilot equipment overview

Equipment type	Description	Location	Installation status, date	Purpose
Conductor temperature sensor	Autonomous MV line sensors measuring the conductor temperature	At both ends of a 40kV line, close to the substations	Installed on 21/07/2025	Provide data to evaluate ICCS's algorithm accuracy in estimating conductor temperature from ambient temperature and current for the RTTR innovation
Relay	Monitors the load of 2 single-phase circuits or 1 three-phase circuit	User premises	Installed in 5 out of 10 homes (17/10/2025)	Provide data on total grid import/export, PV production, appliances load (e.g. oven, stove AC) for NILM and flexibility market UCs
Smart plug	Monitors and controls plug-connected loads up to 12A/16A	User premises	Installed in 5 out of 10 homes (17/10/2025)	Provide appliance load data on (e.g. fridge, freezer, dishwasher, washing machine) for evaluating the accuracy of NILM UC

AC infrared controller	Controls AC via infrareds (similarly to a wireless remote control) and measures temperature and humidity	User premises	Installed in 3 out of 7 homes (17/10/2025)	Enable remote AC setpoint adjustment based on flexibility requests for the flexibility market UC
Smart thermostat	Replaces the existing heat pump thermostat, allowing for remote setpoint control	User premises	Not installed yet (17/10/2025)	Enable remote heat pump setpoint adjustment based on flexibility requests for the flexibility market UC

5.1.4 Feedback collection plan

Feedback will be gathered both from those directly involved in the project and those who would be the end-users from the tools developed during OPENTUNITY.

End-user and stakeholder feedback

Regarding the innovations for which the DSO is the user, feedback will be gathered from Anell's exploitation teams. During the use cases definition, interviews were conducted to better understand the DSO's needs, and which were the key points which would have to be answered for the innovations to fulfil those needs. Towards the end of the pilot, interviews and usability tests will be undertaken in order to gather information on the satisfaction, perceived value, potential improvements and potential barriers to the integration of the tool with Anell's systems and the teams' daily operations. This information will be passed on to the technological partners, for potential further development beyond the scope of the project.

For the innovations where Estabanell Impulsa's residential clients will participate and be the end-users, the retailer will gather feedback from the participants, and in some cases also from clients living in the pilot area who showed some interest but ultimately did not participate in pilot. A survey on the clients' motivation is included in the application process. This survey was written in collaboration with JR and provides them with information on push and pull factors both from participants and those who initially applied but eventually did not want to be part of the project. Two citizen engagement workshops were planned for the Spanish pilot, one took place in Santa Eulàlia de Ronçana in January 2025, and the other in October 2025 in Bigues i Riells. The workshops are also recruitment events for the project, and during the first one there was an informal conversation with the participants on why they were or not interested in joining the project. This information will also be retrieved during the second workshop. During the pilot, the participants will have access to the NILM platform developed by ETRA where, amongst other things, they will be able to provide feedback directly to the technological developer. Finally, towards the end of the project Estabanell Impulsa will share another survey and perform interviews with some of the participants to gather their overall satisfaction and perceived value from the tested innovations. The final survey and interview script will also have the support from JR.

Table 5.3. SP pilot end-user feedback collection plan

What will be collected	Who is involved	Method	Frequency	Use of input

Anell's needs related to OPENTUNITY tools	Anell's exploitation team	Interview	Once during use cases definition	Use cases definition
Satisfaction, potential improvements and barriers	Anell's exploitation team	Interview and usability test	Once towards the end of the pilot	Potential further development
Motivation to participate, push and pull factors	Estabanell Impulsa, clients	Survey, informal interview	Survey is part of participants onboarding. Two informal interviews during citizen engagement workshops	Provide JR with information on push and pull factors
Satisfaction, feedback from the tools	Estabanell Impulsa, clients	Survey, interview	Once towards the end of the pilot	Potential further development

Internal partner feedback

The teams from Anell and Estabanell Impulsa involved in OPENTUNITY have been and will continue to providing feedback to the technology developers from the use cases they are involved in. The feedback consists in exploring the developed tools and comment on their usability, barriers to their use by the exploitation teams and suggestions to better align the tools to the end-user needs. This took place on November 2024 via the Graphical User Interface (GUI) questionnaires provided by the technology developers. Since then, further feedback has been provided to ICCS's network planning tool and ETRA's NILM platform, as new versions are made available to the pilot partners, and it will continue being provided.

Table 5.4. SP pilot internal feedback collection plan

What will be collected	Who is involved	Method	Frequency	Use of input
Feedback on tools usability	Anell/Estabanell Innovation team	Explore tools	As new versions are deployed	Improve tools usability

5.1.5 User scenario assumptions and impacts

The end-users for most of the OPENTUNITY tools tested in the Spanish pilot are personnel from Anell's exploitation team; the exception being the NILM platform, for which clients of Estabanell Impulsa electricity retail are the end-users. In the table below there is a brief description of how the end-users are expected to interact with the different OPENTUNITY tools.

Table 5.5. SP pilot user scenarios

Innovation/tool	Scenario description
ETER (ETRA)	The exploitation team from Anell monitors the grid represented in ETER to detect current congestions or under/over-voltages, to predict future ones or to detect frauds. The information promotes corrective actions, assists in planning or promotes flexibility activation requests. ETER tool is also used for the latter.
RTTR tool (ICCS)	Anell's exploitation team has access to the results for the dynamic line rating and takes them into consideration instead of the conservative static line rating values currently being used

Long-term advanced asset management tool (ICCS)	The exploitation team explores the tool to conclude which smart meters should be replaced in the short-term, and to understand if certain models/brands tend to perform better than others
Network planning tool (ICCS)	The exploitation team explores the tool to gather insights for increasing the RES capacity in the future
NILM platform (ETRA)	Pilot participants monitor their household consumption disaggregated per home appliance. They gather information regarding their appliance's energy efficiency labels. They also consult information regarding the flexibility activations for their household.

For the scenarios described above, it is assumed that the end-users have a good level of familiarity with the different tools and see value in using them. Specifically for the NILM platform, it is assumed that the end-users are checking the tool with certain regularity and find it interesting. If these assumptions are not met, there will be less feedback regarding the tools, but there shouldn't be any significant impact on the demonstration itself. As previously mentioned, the needs and interests from the DSO's exploitation team were collected during the use cases definition and taken into consideration to assure these assumptions are met for the DSO oriented tools as much as possible. Regarding Estabanell Impulsa's clients, the recruitment campaign was designed for an audience with a certain level of interest in technology and innovation, thus more likely to be tech-savvy and interested in the platform and information we make available during the pilot. Estabanell will also onboard the participants on the NILM platform, making sure the available functionalities are clear for all.

For the flexibility market use case, there are some further assumptions made regarding flexibility activation. In the Spanish pilot, flexibility will be activated by changing the set point of air conditioning, heat pumps and/or electric boilers. This means the activations are restricted to the moments when the participants have these devices turned on, both to minimize the impact on the participants' comfort and to test their tolerance to these changes. From the DSO's perspective, the flexibility activations should serve to alleviate the grid in critical moments, thus they should occur in moments of higher voltage volatility or congestion in the electrical grid. That being said, it is assumed that there will be an intersection between the moments when the flexible assets are turned on and the risk of congestion or under/over-voltage is high. If this is not the case, having the flexible assets turned on will be the determining factor, thus flexibility activations will still take place, but the analysis regarding their benefits for the grid might not be as conclusive.

5.2 Deployment plan

Table 5.6. SP pilot deployment plan. The dashed red line represents the start of OPENTUNITY demonstrations.

Spanish pilot site deployment	2023	2024												2025												2026					
	Jan-Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
	M01-M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	M25	M26	M27	M28	M29	M30	M31	M32	M33	M34	M35	M36	M37	M38	M39	M40	M41	M42
NILM & Flexibility market use cases																															
Defining/revisiting recruitment strategy		■	■	■	■		■				■																				
Recruitment campaigns						■		■						■									■								
Planning Citizen Engagement Workshops												■	■							■	■	■									
Citizen Engagement Workshops														■									■								
Participants onboarding						■	■	■	■			■	■	■	■	■							■	■							
Planning installations			■	■	■	■	■					■			■	■	■	■													
Installing needed equipment at participants homes																		■	■	■			■	■							
Demonstration activities																									■	■	■	■	■	■	■
Feedback gathering																							■						■		
Grid-focused use cases																															
Sharing static and historical data		■	■	■			■	■			■	■			■				■												
Setup sending advanced supervision, AMI and energy curves data to ETRA's SFTP server										■	■	■	■	■	■					■	■	■									
SCADA data available via MQTT																						■	■								
Setup to receive results from some of the innovations via MQTT																						■	■								
Planning and installing temperature sensors																	■	■		■											
Using the platforms and providing feedback												■									■	■	■								

5.3 Test cases, datasets and KPIs

A total of 14 test cases were drafted to detail how the OPENTUNITY use cases will be tested in the Spanish pilot. The full versions of these test cases can be found in the annex.

5.3.1 Test cases

In the Spanish pilot, 14 test cases will be demonstrated, their short descriptions are provided below and the full descriptions are included in Annex 1 (section 10.1.3).

Table 5.7. Summary of SP pilot's test cases

Category	Test case ID	Test case name
Horizontal	TC1.1.1	Voltage variation forecast (SP pilot)
	TC1.2.1	NILM identification ability (SP pilot)
	TC1.3.3	State estimation calculation (SP pilot)
	TC1.4.1	RTTR tool for MV lines capacity calculation (SP pilot)
	TC1.5.4	Long term asset management for smart metering equipment of DSOs (SP pilot)
	TC1.8.1.2	Baseline consumption forecast (SP pilot)
	TC1.8.2.2	Flexibility consumption forecast (SP pilot)
	TC1.8.3.2	Dispatch of control signals to assets (SP pilot)
	TC1.10.2	Using flexibility to enhance grid capacity and resiliency (SP pilot)
Pilot-specific	TC4.1.1	Topology detection ability
	TC4.2.1	Non-technical losses detection accuracy
	TC4.3.1	Detection of unexpected island's ability
	TC4.4.1	Critical point detection ability
	TC4.5.1	Improving the grid infrastructure, using grid planning methodologies, while increasing RES integration

TC1.1.1 Voltage variation forecast (SP pilot)

Short description: This test case will analyse the precision of the voltage variation forecast performed in ÉTER and will also check if the voltage variations are within the thresholds defined by the DSO.

Main responsible partners:

- ANELL – Grid Operator, providing historical and real-time data
- ETRA – ÉTER technology provider, with a functionality to analyse the short-term impact of DER in the grid

Involved assets & systems:

- ÉTER
- SCADA (P, Q, V, I) from the nodes
- Weather forecast provider (Open Weather)
- Smart meter data (exported and imported power

Environment: Live

TC1.2.1 NILM identification ability (SP pilot)

Short description: The goal of this test case is to analyse the ability of the NILM module to identify the different loads of households using just the real time smart meter data as an input

Main responsible partners:

- IMPULSA –It provides the consumption data from Spanish pilot
- ETRA – NILM developer

Involved assets & systems:

- Smart meter
- Consumption sensors
- Smart home gateway
- NILM module

Environment: Live

TC1.3.3 State estimation calculation (SP pilot)

Short description: The target is to increase DSO grid observability, especially in LV networks

Main responsible partners:

- ANELL - Grid Operator, providing historical and real-time data
- ETRA – ÉTER technology provider, with a functionality to identify topology

Involved assets & systems:

- ÉTER (which includes the topology of the grid)
- SCADA (P, Q, V, I)
- AMI system (P, Q, V, I)
- Weather forecast provider (Open Weather)

Environment: Live

TC1.4.1 RTTR tool for MV lines capacity calculation (SP pilot)

Short description: The RTTR tool calculates the conductor temperature on different feeder sections based on IEEE738 standard, while also estimating, via machine learning, the current and temperature of the next 6 hours. This test case focuses on the outputs from the RTTR tool

Main responsible partners:

- ANELL: DSO and user of the RTTR tool
- ICCS: Developer of the RTTR tool

Involved assets & systems:

- Hardware: ICCS server hosting the software, ICCS DB server hosting the required datasets
- Software: RTTR tool
- Measurement systems: Overhead power-line monitoring device (Sentrisense Line guard)
- Cloud: Sentrisense API, IoT MQTT broker

Environment: Live

TC1.5.4 Long term asset management for smart metering equipment of DSOs (SP pilot)

Short description: This test case will utilize the long-term module of the advanced asset management tool offering the DSO capabilities to perform end-of-life assessment of smart meters and critical smart meter detection

Main responsible partners:

- ANELL: DSO and user of the asset management tool
- ICCS: Developer of the asset management tool

Involved assets & systems:

- Server hosting the database and the Advanced Asset Management tool
- AMI: DSO Smart meters data collection system for the extraction of measurements
- DSO asset management system: for the extraction of smart meter installation and replacement data
- Software: Asset Management Tool

Environment: Hybrid – real smart meter and asset data from the DSO are processed by the Advanced Asset Management tool in a controlled IT environment, with results validated against actual network conditions

TC1.8.1.2 Baseline consumption forecast (SP pilot)

Short description: The goal of this test case is to forecast the baseline consumption for a particular consumer

Main responsible partners:

- HYP – BFMS responsible partner
- ESTABANELL / ANELL / ETRA – Asset operators at the Spanish pilot
- QUE – Data Space operator

Involved assets & systems:

- Assets at pilot sites, including EMS
- BFMS
- Data Space (Data Space connector deployed at each participant site)

Environment: Live

TC1.8.2.2 Flexibility consumption forecast (SP pilot)

Short description: The target of this test case is to forecast the flexibility consumption for a particular consumer

Main responsible partners:

- HYP – BFMS responsible partner
- ESTABANELL / ANELL / ETRA – Asset operators at the Spanish pilot
- QUE – Data Space operator

Involved assets & systems:

- Assets at pilot sites, including EMS
- BFMS
- Data space (Data Space Connector deployed at each participant site)

Environment: Hybrid – Although most of the test will rely on live data coming from sensors, data coming from other users (like NILM) will also be used, which may need some processing offline.

TC1.8.3.2 Dispatch of control signals to assets (SP pilot)

Short description: This test case focuses on the dispatch of control signal at the assets

Main responsible partners:

- HYP – BFMS responsible partner
- NODES – NODES platform operator
- QUE – Data Space operator
- ESTABANELL / ANELL / ETRA – Asset operators at the Spanish pilot

Involved assets & systems:

- BFMS
- Data space (Data Space connector deployed at each participant site)
- NODES platform
- Assets at pilot sites, including EMS

Environment: Live

TC1.10.2 Using flexibility to enhance grid capacity and resiliency (SP pilot)

Short description: The goal of this test case to evaluate the use of residential assets for grid services

Main responsible partners:

- Anell – DSO
- Estabanell – Aggregator
- HYP – Technical FSP and BFMS
- NODES - FMO

Involved assets & systems:

- Residential assets
- NODES platform
- HYP's BFMS
- ETRA's ETER
- ETRA's BESOS

Environment: Live

TC4.1.1 Topology detection ability

Short description: The target is to identify the inaccuracies on the topological models of the DSO by analysing the data received from the available network sensors and checking its compatibility with the calculated state estimation

Main responsible partners:

- ANELL – Grid Operator, providing historical and real-time data
- ETRA – ÉTER technology provider, with a functionality to detect topology

Involved assets & systems:

- ÉTER (which includes a topology identification module)
- SCADA (P, Q, V, I)
- AMI system (P, Q, V, I)

Environment: Hybrid – Data coming from SCADA won't be live and will come with some delay so the test will not be live but using real data from SCADA (and AMI system).

TC4.2.1 Non-technical losses detection accuracy

Short description: The goal from this test case is to detect potential theft attempts in the grid

Main responsible partners:

- ANELL – Grid Operator, providing historical and real-time data
- ETRA – ÉTER technology provider, with a functionality to detect non-technical losses

Involved assets & systems:

- ÉTER (which includes a topology identification module)

- SCADA (P, Q, V, I)
- AMI system (P, Q, V, I)

Environment: Hybrid – Data coming from SCADA won't be live and will come with some delay so the test will not be live but using real data from SCADA (and AMI system).

TC4.3.1 Detection of unexpected island's ability

Short description: This test case focuses on the detection of blown fused and pinpointing its exact location and phase through the monitoring of the voltage at end user level

Main responsible partners:

- ANELL – Grid Operator, providing historical and real-time data
- ETRA – ÉTER technology provider, with a functionality to detect unexpected islands

Involved assets & systems:

- ÉTER (which includes a topology identification module)
- SCADA (P, Q, V, I)
- Weather forecast (Open weather)
- PLC Concentrators

Environment: Simulated via laboratory experiments

TC4.4.1 Critical point detection ability

Short description: The aim of this tool is to evaluate the sections of the LV network that are more fragile or critical given the current network topology

Main responsible partners:

- ANELL – Grid Operator, providing historical and real-time data
- ETRA – ÉTER technology provider, with a functionality to detect critical points

Involved assets & systems:

- ÉTER (which includes a topology identification module).
- SCADA (P, Q, V, I).
- Weather forecast (Open weather)

Environment: Simulated

TC4.5.1 Improving the grid Infrastructure, using grid planning methodologies, while increasing RES integration

Short description: This test case will identify the best upgrades in the system that maximize the RES capacity. The DSO will set in the user interface (UI) the necessary settings, like budget constraints and flexibility constraints and perform planning with a goal to maximize RES penetration

Main responsible partners:

- ANELL: DSO and user of the network planning tool
- ICCS: Developer of the network planning tool

Involved assets & systems:

- Software: network planning tool
- Hardware: ICCS server hosting the software
- System topology (excel format)
- Historical data of substation loading

- Types of lines considered for upgrade

Environment: Simulated

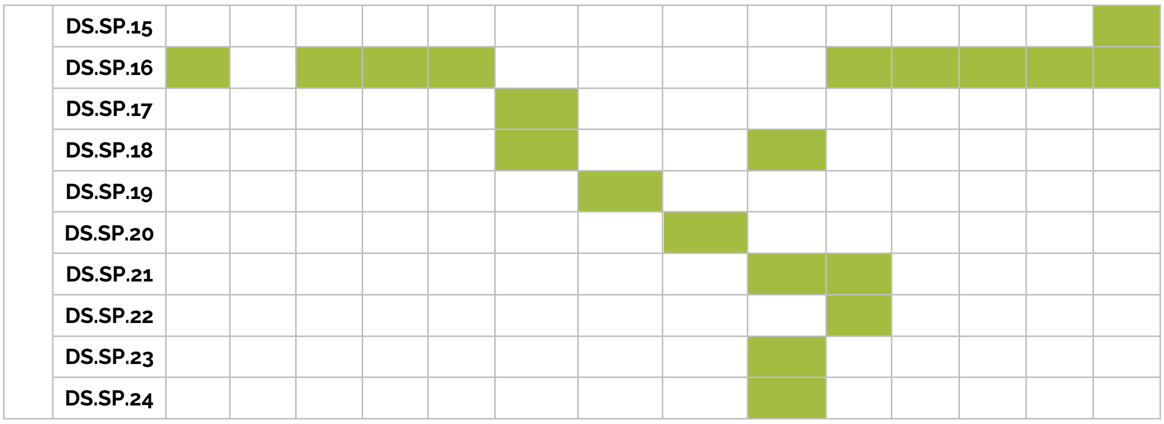
5.3.2 Datasets

Table 5.8. Datasets provided by SP pilot for test cases

Dataset ID	Dataset name
DS.SP.01	Smart meter and submetering data
DS.SP.02	Voltage variation data in Spanish pilot
DS.SP.03	Electrical grid estimated measurements in Spanish pilot
DS.SP.04	Alerts inserted in lines with suspicious activity
DS.SP.05	Real-time operational data from DSO's SCADA
DS.SP.06	Topological data of the lines
DS.SP.07	Historical current measurements
DS.SP.08	Real-time operational data from dynamic line rating (DLR) sensors
DS.SP.09	Environmental forecasts
DS.SP.10	Smart meter historical data
DS.SP.11	Geodata of the secondary substations
DS.SP.12	Smart meter SFTP data
DS.SP.13	Load profile (power curves)
DS.SP.14	Substation power factor data (cosφ)
DS.SP.15	Information on the lines that will be considered for possible upgrade
DS.SP.16	Distribution network topology
DS.SP.17	Asset power consumption
DS.SP.18	Asset baseline power consumption forecast
DS.SP.19	Asset flexibility power consumption forecast
DS.SP.20	Dispatch of control signals to assets at pilot sites
DS.SP.21	Power curves, including voltages at delivering points
DS.SP.22	Grid topology in the considered period
DS.SP.23	Grid infrastructure – high level information
DS.SP.24	Asset data

Table 5.9. SP pilot mapping datasets with test cases

		Test cases													
		1.1.1	**1.2.1**	**1.3.3**	**1.4.1**	**1.5.4**	**1.8.1.2**	**1.8.2.2**	**1.8.3.2**	**1.10.2**	**4.1.1**	**4.2.1**	**4.3.1**	**4.4.1**	**4.5.1**
Datasets	**DS.SP.01**														
	DS.SP.02														
	DS.SP.03														
	DS.SP.04														
	DS.SP.05														
	DS.SP.06														
	DS.SP.07														
	DS.SP.08														
	DS.SP.09														
	DS.SP.10														
	DS.SP.11														
	DS.SP.12														
	DS.SP.13														
	DS.SP.14														



5.3.3 KPIs

5.3.3.1 Summary and mapping of SP pilot KPIs

Table 5.10. Summary of SP pilot's KPIs

New KPI ID	Old KPI ID	Title	Action	Comment
KPI.SE.01	KPI_01	Variability of the voltage	Kept	-
KPI.NILM.01	KPI_02	NILM F1	Kept	-
KPI.SE.02	KPI_03	State estimation MAPE	Updated	Renamed and adapted to SE
KPI.RTTR.01	KPI_04	Capacity increase by DLR	Updated	Corrected a typo in the measurement unit
KPI.RTTR.02	KPI_05	Maximum line temperature underestimation	Kept	-
KPI.AAM.01	KPI_06	Accuracy on asset condition	Kept	-
-	KPI_08	Increase in RES penetration	Removed	Already covered by KPI.GPO.04
KPI.HEMS.01	KPI_10	Demand forecasting accuracy	Kept	-
KPI.HEMS.02	KPI_11	Flexibility delivery precision	Kept	-
KPI.HEMS.03	KPI_12	Flexibility potential	Kept	-
KPI.HEMS.04	KPI_13	GHG reduction	Kept	-
KPI.HEMS.05	KPI_14	Load reduction/increase	Kept	-
KPI.HEMS.06	KPI_15	Rate of successful DT events	Kept	-
KPI.GPO.03	KPI_43	Decrease in investment costs	Updated	Corrected minor typos
KPI.GPO.04	KPI_26	Increase in RES hosting capacity	Updated	Corrected minor typos
KPI.SP.01	KPI_33	Topology detection MAPE	Updated	Changed the metric from F1 score to MAPE
-	KPI_34	Non-technical losses detection rate	Removed	Already covered by KPI.SP.04
-	KPI_35	Fraud detection accuracy	Removed	Already covered by KPI.SP.04
KPI.SP.02	KPI_36	Fraud location detection error	Updated	Detailed calculation steps
KPI.SP.03	KPI_37	Fraud detection benefit	Updated	Overall description and steps modified to adjust it to actual data available.
KPI.SP.04	KPI_38	Fraud detection F1	Updated	Overall description and steps modified to adjust it to actual data available.

KPI.SP.05	KPI_39	Accuracy of fuse burn location	Updated	Overall description and steps modified to adjust it more to the test case.
KPI.SP.06	KPI_40	Outage recovery time after fuse burn	Updated	Renamed and modified to adjust it more to the test case.
-	KPI_41	Detection time	Removed	The implementation of this use case has evolved over time, and this KPI no longer applies
KPI.SP.07	KPI_42	Critical points detection	Updated	Renamed and modified to adjust it more to the test case
KPI.SP.08	KPI_17	Voltage volatility reduction	Updated	Adapted to Spanish pilot
KPI.SP.09	KPI_19	Line congestion reduction	Updated	Adapted to Spanish pilot

Table 5.11. SP pilot mapping KPIs with test cases

		Test cases													
KPIs		**1.1.1**	**1.2.1**	**1.3.3**	**1.4.1**	**1.5.4**	**1.8.1**	**1.8.2**	**1.8.3**	**1.10.2**	**4.1.1**	**4.2.1**	**4.3.1**	**4.4.1**	**4.5.1**
	KPI.SE.01	■													
	KPI.NILM.01		■												
	KPI.SE.02			■											
	KPI.RTTR.01				■										
	KPI.RTTR.02				■										
	KPI.AAM.01					■									
	KPI.HEMS.01						■								
	KPI.HEMS.02								■						
	KPI.HEMS.03						■	■							
	KPI.HEMS.04							■	■						
	KPI.HEMS.05							■	■						
	KPI.HEMS.06								■						
	KPI.GPO.03														■
	KPI.GPO.04														■
	KPI.SP.01										■				
	KPI.SP.02											■			
	KPI.SP.03											■			
	KPI.SP.04											■			
	KPI.SP.05												■		
	KPI.SP.06												■		
	KPI.SP.07													■	
	KPI.SP.08									■					
	KPI.SP.09									■					

Table 5.12. SP pilot mapping KPIs with strategic objectives

		KPIs																						
Strategic objectives		**KP.SE.01**	**KPI.NILM.01**	**KPI.SE.02**	**KPI.RTTR.01**	**KPI.RTTR.02**	**KPI.AAM.01**	**KPI.HEMS.01**	**KPI.HEMS.02**	**KPI.HEMS.03**	**KPI.HEMS.04**	**KPI.HEMS.05**	**KPI.HEMS.06**	**KPI.GPO.03**	**KPI.GPO.04**	**KPI.SP.01**	**KPI.SP.02**	**KPI.SP.03**	**KPI.SP.04**	**KPI.SP.05**	**KPI.SP.06**	**KPI.SP.07**	**KPI.SP.08**	**KPI.SP.09**
	SO1. Decarbonization of EU society	■	■		■	■								■	■									
	SO2 Citizen and stakeholder empowerment		■					■	■	■	■	■	■											

	SO3 Ensure quality of supply in a context of increase of RES																							

5.3.3.2 Pilot site baseline overview

Each KPI related to the Spanish pilot needs to be calculated after demonstrations and benchmarked with state-of-the art or business as usual (BAU) figures. We present here the baseline methodology selected for each KPI, with its value (or expected value) marked in **orange**. When OPENTUNITY innovation tools are expected to bring a relevant improvement, we also argue for our estimated target, marked in **red**.

KPI.SE.01 Variability of the voltage

± 10% is the maximum voltage variation allowed (during 95% of the time) in according to UNE 50.160. This figure will serve as a reference value for this KPI. This value will serve as a baseline value, ensuring that within the tests of the *Short-term analysis of the impact of DER in the Distribution grid*, this value is respected, and trying to reach even a lower figure of **± 5%**.

KPI.NILM.01 NILM F1

Currently, there is no method for disaggregating energy consumption data in place in the pilots, so the project is providing a new service that opens the door to new impacts. In terms of technical performance, there are Spanish grid utilities that have their own disaggregation methods and reach 80% of accuracy. Considering this value and to further improve the performance, the baseline for OPENTUNITY has been set to **80%**. F1 score, which considers the accuracy, precision and recall of the classes to predict (ON and OFF detections) calculated in this KPI could be increased in the project to **at least 85% on average**, considering each appliance monitored.

KPI.SE.02 State estimation MAPE

The performance of state estimation algorithms depends on the observability of the grid and the real measurements available. However, research estimates the errors as follows:

- **Voltage: ±2%**
- **Angle: ±5%**
- **Power flows: ±10%**
- **Loads: ±10%**

OPENTUNITY techniques are expected to leverage Physic Informed Neural Networks (PINNs) to ensure keeping the MAPE lower than these thresholds (the target is to **lower them about 50%**).

KPI.RTTR.01 Capacity increase by DLR

System operators use static thermal ratings with conservative weather assumptions to ensure network security under all operating conditions. By fixing high ambient temperature and low wind speed, the approach avoids the risk of thermal overloading, but at the cost of significant underutilization of the actual line capacity.

While overhead lines are constructed to endure the peak summer conditions, they frequently operate under less severe weather for most of the year, allowing for potential increases in line capacity by up to 200%. According to ENTSO-E, traditional static thermal ratings for overhead lines are determined under conservative assumptions — typically set for worst-case summer conditions

(e.g., ambient ~40 ˚C, wind ~0.6 m/s, high solar gain) ensuring network security in the absence of real-time monitoring.
The KPI is defined as follows:

$$\Delta P_{av}^{max} = \sqrt{3}\, V_{nom} \frac{\sum_{i=1}^{N} I_{max,\ dynamic} - I_{max,\ static}}{N}$$

Where:

- $I_{max,\ dynamic}$: 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

When the RTTR tool is not applied (i.e. baseline), the line ampacity of the line in the abovementioned formula for the calculation of ΔP_{av}^{max}, is the same as the static line rating, thus their difference – i.e. the KPI baseline – is calculated as **zero**.

KPI.RTTR.02 Maximum line temperature underestimation

In practice, system operators rarely measure conductor or cable temperatures along the entire network. Without **Real-Time Thermal Rating**, they rely on deterministic, conservative approaches to ensure the assets are never overloaded.

For this study, the baseline scenario used to calculate the Static Thermal Rating (KPI.RTTR.01) assumes a maximum allowable conductor temperature of T_max = 85˚C[1], which sets the thermal limit for this baseline scenario. This approach, consistent with methodologies employed by system operators, uses fixed, worst-case weather conditions:

- **Ambient air temperature:** Ta=45 °C
- **Wind speed at conductor height:** m/sv=0.6 m/s
- **Wind–conductor yaw angle:** θ=90°
- **Global solar irradiance:** W/m^{2}G=1000 W/m^2
- **Conductor surface emissivity:** ε=0.9
- **Solar absorptivity:** αs=0.5

This baseline scenario represents the conventional STR approach, ensuring network security under worst-case environmental conditions without real-time adjustments.

The KPI is calculated as:

$$Max\ Temperature\ Underestimation(°C) = \max_{i=1:N}(|T_{measured} - T_{\text{estimated}}|)I_i$$

Where:

- $T_{\text{estimated}}$: 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

In the abovementioned formula, T_max = 85˚C can be considered as $T_{\text{estimated}}$, in order to calculate the baseline value for this KPI. In the case of the Spanish pilot, actual data from the Centelles–

[1] Additional information for the relevant calculations is provided in D5.1 – OPENTUNITY power flow developments (v1).

Tarradell line were used. These data were recorded using a line monitoring device installed along the line, with the data retrieved from the device's cloud-based platform through the provided API. The data spans the period from 24 July 2025 to 11 September 2025. To align with the granularity of the DLR estimation, the data were resampled to an hourly frequency. The table below shows a sample of the data.

Table 5.13. Data sample used for the baseline calculation of KPI.RTTR.02 in the Spanish pilot

Date	Time	Conductor temperature
2025-07-24	00:00:00+00:00	27.304384
2025-07-24	01:00:00+00:00	27.575646
2025-07-24	02:00:00+00:00	27.288570
...		...
2025-09-11	21:00:00+00:00	23.646017
2025-09-11	22:00:00+00:00	23.242585
2025-09-11	23:00:00+00:00	22.779118

According to the aforementioned formula, the baseline for this KPI is calculated as $Max\ Temperature\ Underestimation\ (°C)$ = **68.05**.

KPI.AAM.01 Accuracy on asset condition

The KPI is defined as follows:

$$Accuracy = 100\frac{\sum_{i=1}^{N} I}{N}$$

Where:

- I: equals to 1 if for asset i if the prediction condition category is the actual category provided by the DSO
- N: Number of samples

Since the OPENTUNITY advanced management tool is not applied yet, the baseline for this KPI is **0**.

KPI.HEMS.01 Demand forecasting accuracy

As described in D2.1, this KPI is calculated using the following formula:

$$MAE_{forecast} = \frac{\sum_{t=1}^{T} \left| P_{act,t} - P_{b,t} \right|}{T}$$

Where:

- $MAE_{forecast}$: mean absolute error between the actual and the forecasted demand (baseline power consumption), 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 ($t \in 1, \dots, T$)

To calculate the baseline value for this KPI, one should consider that the tool (BFMS) is not applied. In the absence of the BFMS, the baseline power consumption is considered equal to the power consumption of the previous day. The KPI is then calculated by subtracting the day before power consumption from the actual power consumption for the day of interest and for the same timeframe.

This value changes dynamically every day, based on the asset, the season and the occupant preferences.

KPI.HEMS.02 Flexibility delivery precision

As described in D2.1, this KPI is calculated using the following formula:

$$FD_{error} = \frac{\sum_{t=1}^{T} |P_{del,t} - P_{bid,t}| \cdot I_t}{\sum_{t=1}^{T} P_{bid,t}} \cdot 100$$

Where:

- 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 bid 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 ($t \in 1, \ldots, T$)

To calculate the baseline value for this KPI, one should consider that the tool (BFMS) is not applied. In the absence of the BFMS, the delivered flexibility would be equal to zero. This would result in a **0%** flexibility delivery precision value for the baseline scenario of this KPI.

KPI.HEMS.03 Flexibility potential

As described in D2.1, this KPI is calculated using the following formula:

$$E_{flex} = \sum_{t=1}^{T} (P_{b,t} - P_{opt,t})$$

Where:

- 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 ($t \in 1, \ldots, T$)

To calculate the baseline value for this KPI, one should consider that the tool (BFMS) is not applied. In the absence of the BFMS, the baseline power consumption is considered equal to the power consumption of the previous day; the same assumption applies for the optimized power consumption. This results in a **0kWh** flexibility potential for the baseline scenario of this KPI.

KPI.HEMS.04 GHG reduction

As described in D2.1, this KPI is calculated using the following formula:

$$GHG_{Reduction} = EF \cdot \sum_{t=1}^{T} (P_{act,t} - P_{DR,t})$$

Where:

- $GHG_{Reduction}$: 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 ($t \in 1, \ldots, T$)

To calculate the baseline value for this KPI, one should consider that the tool (BFMS) is not applied. In the absence of the BFMS, the adjusted power consumption is considered equal to the actual power consumption. This results in a **0 gCO_2eq** GHG reduction for the baseline scenario of this KPI.

KPI.HEMS.05 Load reduction/increase

As described in D2.1, this KPI is calculated using the following formula:

$$E_{change} = \sum_{t=1}^{T} (P_{act,t} - P_{DR,t})$$

Where:

- 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 ($t \in 1, \dots, T$)

To calculate the baseline value for this KPI, one should consider that the tool (BFMS) is not applied. In the absence of the BFMS, the adjusted power consumption is considered equal to the actual power consumption. This results in a **0 kWh** load reduction/increase for the baseline scenario of this KPI.

KPI.HEMS.06 Rate of successful DR events

As described in D2.1, this KPI is calculated using the following formula:

$$R_{S,DR} = \frac{N_{S,DR}}{N_{total,DR}} \cdot 100\%$$

Where:

- $R_{S,DR}$: rate of successful DR events (percentage)
- $N_{S,DR}$: number of successful DR events
- $N_{total,DR}$: number of total DR requests

To calculate the baseline value for this KPI, one should consider that the tool (BFMS) is not applied. In the absence of the BFMS, the number of successful DR events is considered equal to zero. This results in a **0%** rate of successful DR events for the baseline scenario of this KPI.

KPI.GPO.03 Decrease in investment costs

The KPI is defined as follows:

$$\Delta P_{RES} = 100 \frac{\mathrm{C}_{BAU} - C_{\mathrm{R\&I}}}{\mathrm{C}_{BAU}}$$

Where:

- $\mathrm{C_{R\&I}}$: Cost of network upgrades estimated in the pilot with optimal scheduling of flexibility and network investements.
- $\mathrm{C_{BAU}}$: Cost of network upgrades estimated with existing methodologies applied in each pilot.

When the planning tool is not applied (i.e. baseline), $C_{\mathrm{R\&I}}$ will be equal to the cost of BAU scenario, C_{BAU}. Thus, according to the abovementioned formula for the calculation of ΔP_{RES}, the baseline for this KPI is **0**.

KPI.GPO.04 Increase in RES hosting capacity

The KPI is defined as follows:

$$\Delta C_{RES} = 100 \frac{\mathrm{RES}_{\mathrm{capacity}_{\mathrm{R\&I}}} - \mathrm{RES}_{\mathrm{capacity}_{BAU}}}{\mathrm{RES}_{\mathrm{capacity}_{BAU}}}$$

Where:

- $\mathrm{RES_{capacity}}_{\mathrm{R\&I}}$: Penetration of renewables with network planning that considers flexibility optimization
- $\mathrm{RES_{capacity}}_{\mathrm{BAU}}$: Penetration of renewables with network planning in a BAU scenario.

When the network planning tool is not applied (i.e. baseline), the $\mathrm{RES_{capacity}}_{\mathrm{R\&I}}$ in the calculation of ΔC_{RES} will be the same with the business as usual scenario, $\mathrm{RES_{capacity}}_{BaU}$. Thus, the KPI value for the baseline is calculated equal to **zero**.

KPI.SP.01 Topology detection MAPE

There is currently no topology detection algorithm deployed in any pilot to compare with (so we set it at 0). Nevertheless, state-of-the-art in the field accounts for an accuracy of **60%**. Our goal is to enhance this level but calculating the MAPE, being or target MAPE **<40%**.

KPI.SP.02 Fraud location detection error

The baseline included of **500-600m** corresponds to the precision Anell usually has when suspecting there are Non-Technical Losses in the grid. Using a technical solution like the OPENTUNITY module should delimit this precision to **100-200m**.

KPI.SP.03 Fraud detection benefit

Usually, when there is a suspicion of a fraud, it takes about 2 to 3 inspections to find the place. It also depends on the type of fraud. Frauds due to Marijuana plantation are 8 hours of work (plus involvement of the police) leading to a cost of 880€. For other frauds it is needed 4 hours that led to 440€. Normally it takes about 3 visits to validate the exact place of the fraud so in average it could take **1980€ per fraud**. The detected frauds are then paid. The aim is to lower that number up to 1 visit leading to **660€ (66% reduction)**.

KPI.SP.04 Fraud detection F1

Statistics of fraud detection in low voltage European networks show a detection rate of **30%-50%** in a 12-month period. Our goal is to achieve **80%** of F1.

KPI.SP.05 Accuracy of fuse burn location

There is no baseline for this KPI since there is no system installed currently in the pilot (so we set it at **0**), but we expect an accuracy of **95%** in the detection which is the accuracy reached is some lab research.

KPI.SP.06 Outage recovery time after fuse burn

The average time that ANELL needs to detect and substitute a burned fuse is **90 mins**. The objective is to **reduce this time by 25%** thanks to early detection.

KPI.SP.07 Critical points detection

Currently there are no baseline to compare with since there is currently no critical points detection algorithm deployed in any pilot, and it was not possible to find figures (so we set it at **0**). However, we expect accuracy in the critical point identification of **50%**.

KPI.SP.08_Voltage volatility reduction

According to the Spanish norm UNE 50.160, **± 10%** is the maximum voltage variation allowed (during 95% of the time), thus this value will serve as a baseline. We hope to reach a lower figure of **± 5%**

during flexibility activations in the pilot. While this KPI is similar to KPI.SE.01, it focuses on the evaluation of the use of flexibility for voltage control in an isolated manner, while KPI.SE.01 evaluates ETRA's impact of DER module of ÉTER.

KPI.SP.09_Line congestion reduction

At Anell, when a low voltage line reaches **80%** capacity it is considered congested, and an alarm is triggered. This value will then be considered as a baseline. We hope to see that during the pilot's flexibility activations line saturation won't reach **50%**.

5.4 Demonstration plan

Table 5.14. SP pilot demonstration plan. The dashed red lines represent the start and end of OPENTUNITY demonstrations.

Spanish pilot demonstration plan		2025				2026								
	Jan 2023 - Aug 2025	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	M01-M32	M33	M34	M35	M36	M37	M38	M39	M40	M41	M42	M43	M44	M45
TC1.1.1 Voltage variation forecast														
ETER's integration with pilot's data and data sources		■												
Models training		■	■											
Develop and deploy new version of ETER		■	■											
Models testing and calculation of the forecast's accuracy						■	■	■	■	■	■			
TC1.2.1 NILM identification ability in Spanish pilot														
ETRA's integration with equipment installed at participants' homes		■												
Models training		■												
Deployment of the platform/app and participants' onboarding		■	■	■										
Models testing with pilot data					■	■				■	■			
TC1.3.3 State estimation calculation in Spanish pilot														
ETER's integration with pilot's data and data sources		■												
Models training		■	■											
Develop and deploy new version of ETER		■	■											
Models testing and calculation of the state estimation accuracy			■	■		■	■	■	■	■	■			
TC1.4.1 RTTR tool for MV lines capacity calculation														
ICCS's integration with pilot's data and data sources		■	■											
Models training				■										
Deployment and integration of ICCS RTTR tool				■	■									
Tool testing and performance review						■	■	■	■	■	■			
TC1.5.4 Long term asset management for smart metering equipment of DSOs														
ICCS's integration with pilot's data and data sources		■	■											
Models training				■										
Deployment and integration of ICCS long-term asset management tool				■	■	■								
Tool testing and performance review							■	■	■	■	■			
TC1.8.1.2 Baseline consumption forecast														
Asset consumption data collection from the pilot		■	■	■	■									
BFMS training and testing		■	■	■	■									
Integration with ETRA's and NODES' platforms		■	■											
Execution during pilot					■	■	■	■		■	■			
TC1.8.2.2 Flexibility consumption forecast														
BFMS training and testing		■	■	■	■									
Integration with ETRA's and NODES' platforms		■	■											
Execution during pilot					■	■	■	■		■	■			

TC1.8.3.2 Dispatch of control signals to assets at pilot sites
Integration with ETRA's and NODES' platforms
Execution during pilot
TC1.10.2 Spain - Using flexibility to enhance grid capacity and resiliency
Participants (and assets) onboarding and sensors/actuators installation
Integration between ETRA's platforms, Hypertech's BFMS and NODES' marketplace
Flexibility prices analysis
Flexibility trading during pilot
TC4.1.1 Topology detection ability
ETER's integration with pilot's data and data sources
Models training
Develop and deploy new version of ETER
Models testing and calculation of the accuracy
TC4.2.1 Non-Technical Losses detection accuracy
ETER's integration with pilot's data and data sources
Models training
Develop and deploy new version of ETER
Models testing and calculation of the detected frauds accuracy
TC4.3.1 Detection of unexpected island's ability
ETER's integration with pilot's data and data sources
Laboratory experiments and collection of relevant data
Models training
Develop and deploy new version of ETER
Models testing and calculation of the blown fuse detection accuracy
TC4.4.1 Critical point detection ability
ETER's integration with pilot's data and data sources
Models training
Develop and deploy new version of ETER
Models testing and analysis of the simulations results
TC4.5.1 Improving the grid Infrastructure, using grid planning methodologies, while increasing RES integration
ICCS's integration with pilot's data and data sources
Deployment and integration of ICCS Network Planning tool
Tool testing and performance review

5.5 Risk management plan

Table 5.15. SP pilot risk management plan

Risk ID	Risk description	Category	Likelihood	Impact	Mitigation/contingency action
SP.01	Testing UC4.3 in a real environment may not be possible since fuse faults occur only during actual grid failures. Detection of blown fuses might not be possible using real data	Technical	High	Low	This UC will be tested in a controlled environment in a laboratory or in a simulation.
SP.02	Lack of an automated and easy way to share real-time data from certain sources with the project partners	Technical / Data	Medium	Medium	Work closely with the relevant departments of Estabanell and our SCADA and Advanced Supervision providers. The SCADA data shall be sent via MQTT, while the remaining data will be sent via SFTP to a server from ETRA.
SP.03	Ongoing Advanced Supervision implementation and unreliable AMI data limit observability and hinder congestion and voltage forecasts in the relevant grid areas for the LFM, impacting UC1.10	Technical / Data	Medium	Low	Work closely with the relevant departments of ANELL and monitor the situation as new participants register to the pilot. Use state estimation to calculate missing values.
SP.04	FSP's lack of knowledge and/or experience for fulfilling some of their activities, impacting UC1.10	Technical	Low	Low	Work together with partners involved in the LFM, to exchange knowledge and support
SP.05	Failing to activate flexibility when requested for technical reasons, such as sensor/actuator failure or lack of connectivity, impacting UC1.10	Technical	Low	High	Install Wi-Fi extenders when needed. Monitor equipment performance and connectivity
SP.06	Failing to respect grid constraints although flexibility request is fulfilled, due to neighbouring users changing their consumption, cancelling the flexibility service effect, impacting UC1.10	Technical / User-related	Medium	Low	Monitor the whole area and see if more flexibility requests are needed to fulfil our goal
SP.07	Failing to detect activated flexibility given the baseline and detection algorithm used, impacting UC1.10	Technical	Low	Medium	Regular communication with the end-users to know their perspective and share that information with the technological developers
SP.08	Poor communication or misunderstandings between partners may cause delays, misalignment in the tool's development and implementation, failing to meet user's expectations for functionality and UI, hindering future adoption	Organizational	Low	Medium	Close and frequent communication among partners
SP.09	UC1.4 testing of RTTR requires costly temperature sensors, and budget likely allows purchasing only one	Technical	Low	Medium	Analysis of the conductor to find highest temperature rise location, install the meter there as a measurement to obtain the highest temperature

					of the conductor, which could indicate the actual rating to compare the innovation with
SP.10	Lack of human resources for installing the necessary equipment. This may affect UCs 1.4, 1.8 and 1.10	Organizational	Medium	High	Work closely with relevant departments of Estabanell. Subcontract personnel if neede.
SP.11	Delays in the demonstration of the pilot due to e.g. trial and error, low responsiveness from the participants, extension of the recruitment for the pilot with a citizen engagement workshop, may complicate testing the pilot in due time	Organizational	High	Medium	Keep track of different milestones and predict needed time to complete the upcoming ones
SP.12	Lack of clients interested in participating in the NILM or LFM pilots, in other words, UCs 1.2, 1.8 and 1.10	User-related	High	High	Reach a large audience, emphasise key messages and highlight the pilot participation advantages. Organize a citizen engagement workshop with a second recruitment round to present a first version of the tool.
SP.13	Participants show little activity and responsiveness to our communications, delaying and hindering the gathering of information, pilot planning, and feedback collection. This affects UCs 1.2, 1.8 and 1.10.	User-related	High	Medium	Tune the key message and recruitment campaign to a client profile which tends to be more actively involved and who has interest in sustainability and/or new technologies
SP.14	As a consequence of low participation, and/or late registration in the pilot, the number of clients participating and the duration of their participation is low, leading to small volumes of data. This affects UCs 1.2, 1.8 and 1.10.	User-related / Data	High	Medium	Use open-source data for an initial version of the NILM algorithm, baseline calculation and demand-response optimization
SP.15	Failing to active flexibility because the requests don't match the users' needs, who then counteract on the activation, impacting UC1.10	User-related	Medium	Medium	Understand and integrating clients' limitations and priorities when optimizing and selecting flexibility services
SP.16	Final product may not fully align with all user expectations, hindering its future adoption by the DSO or the end-users' interaction with it	Technical / User-related	Medium	Medium	Work closely with the product and UI developers, gather feedback from end-users (DSO staff or clients), and initiate feedback loops
SP.17	Lack of information to calculate certain KPIs and/or evaluate the effectiveness of some UCs	Technical/Data	Medium	Low	Define calculation steps, link KPIs to datasets in advance. Use experience and data from similar UCs in other pilots to support these evaluations.

6 Slovenian pilot site

6.1 Pilot site characterization

The Slovenian pilot site consists of three separate pilot setups, each focused on different aspects of OPENTUNITY's innovations.

- The first two pilot sites are DSO focused, where existing parts of the grids operated by Elektro Ljubljana (EL) and Elektro Primorska (EP) are used to validate WP5 innovations, such as topology identification, state estimation, and advanced asset management. They differ in the type of network they cover: the first one is industrial, while the second is rural.
- The third pilot site focuses on the forecasting and optimal selection of available flexibility, using data from real fleets of EV charging stations and HEMS devices to support flexibility-related innovations.

6.1.1 Pilot site description

6.1.1.1 EP pilot setup – industrial park in Ajdovščina

This pilot is located in the Ajdovščina industrial zone, located in the southwest of Slovenia. The area includes 2 medium-voltage (MV) feeders and 10 MV/LV secondary substations, supplying a diverse range of industrial consumers—from small to large enterprises. Some are connected at the low-voltage level, while others are directly connected to the MV grid through their own transformers.
The Ajdovščina industrial park is rapidly growing and presents a suitable environment for testing innovations in a more industrial grid context. It enables the demonstration of WP5 tools (grid planning, advanced asset management, state estimation, topology identification) in a network with high and variable loads, dynamic operational profiles, and industrial customer behaviour.

6.1.1.2 EL pilot setup – Grosuplje rural network and Mengeš MV feeder

This pilot is located in the Grosuplje area, central Slovenia, within a rural section of Elektro Ljubljana's distribution network. It includes part of one 20 kV feeder, connected to the Grosuplje 110/20 kV substation. The area was selected due to its history of frequent outages, making it a relevant setting for testing innovations related to state estimation, topology identification, and advanced asset management.

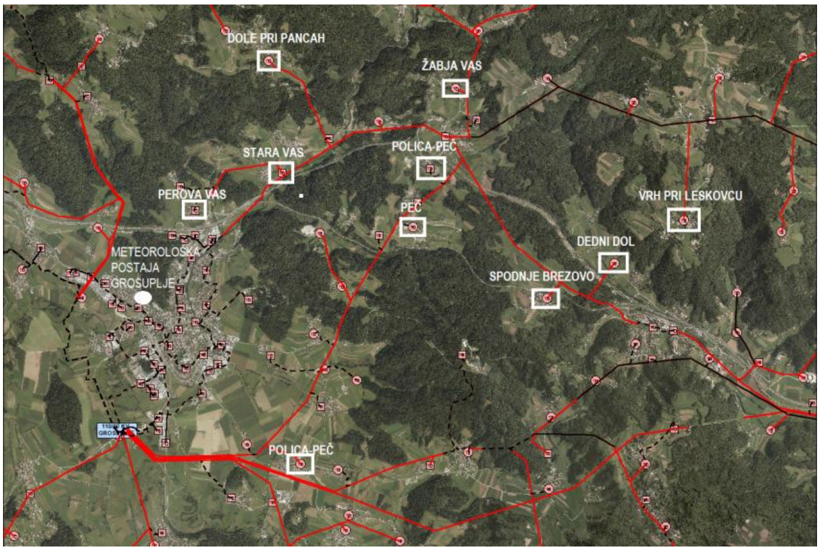


Figure 6. Overview of the MV lines in the Slovenian EL pilot around the town Grosuplje. The white rectangles represent transformer substations.

The pilot setup includes a mix of overhead and underground infrastructure across both medium and low voltage levels. A set of 10 transformer substations, already equipped with smart meters and sensors, was chosen for the demonstration. These substations are capable of delivering near real-time data, and are located near a meteorological station, enabling the integration of weather data into testing activities. At this part of the pilot site, we are facing challenges on how to establish reliable data provision from the temperature and humidity sensors installed at the MV/LV transformer stations. The main problem is that the data path is different from the usual smart meters data.

In addition to this network section, and in order to ensure high-quality historical and near real-time data provision, EL decided to add a second network section. From the perspective of consumption and inhabitants, this second site is slightly more "city-like". The pilot site is located approximately 15 km from the capital city, Ljubljana, and starts at the HV/MV distribution substation Mengeš, involving one feeder—the J26 overheadline 20 kV line Radomlje. Along this MV feeder, 33 MV/LV transformer stations are connected, and 9 of them were selected to be included in the project. On the LV side, 436 grid users are connected, and EL is capable of providing both historical and near real-time 15-minute data for all LV smart meters as well as all sum-smart meters installed in the transformer stations. This part of the EL distribution grid will be used for testing both long- and short-term asset management, as well as for network planning tools.

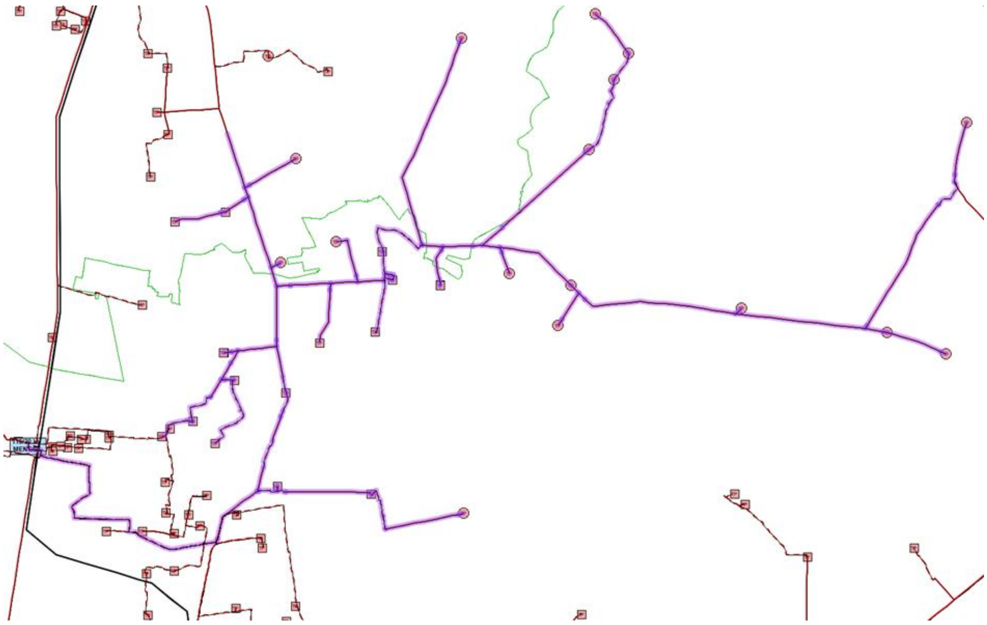


Figure 7. EL pilot second network section. With violet colour is marked the MV level grid- Distribution substation Mengeš, J26 MV feeder Radomlje

This environment supports the demonstration of WP5 innovations in a rural grid context, complementing the industrial setup of the EP pilot

6.1.1.3 Flexibility-focused pilot site setup

The third part of the Slovenian pilot focuses on **data-driven flexibility management**, as part of the "optimal selection of available flexibility" OPENTUNITY innovation. Two operational fleets are included:

- **Reduxi HEMS devices** installed in residential buildings (provided by Amibit).
- **EV charging stations** primarily used for car sharing (operated by AVANTCAR).

The pilot enables:

- Development and testing of baseline forecasting models at both individual and portfolio level.
- Validation of the market selection algorithm developed by SETUP.
- Demonstration and evaluation of the optimal flexibility allocation algorithm developed by UL.

By combining real data from both fleets with algorithmic innovations, the pilot provides a comprehensive environment for testing how flexibility can be forecast, allocated, and valorised in different markets.

6.1.2 Pilot site roles

Table 6.1. SI pilot site roles

Partner	Role in the pilot	Main responsibilities
UL	Pilot leader, technology provider	Leads the innovation on "optimal selection of available flexibility" and oversees pilot activities.

IRI UL	Research & technical support	Assists UL in pilot implementation and innovation development.
SETUP	Aggregator	Provides market expertise and enables the use of the aggregation platform
Amibit	Data provider	Supplies data from the Reduxi HEMS portfolio
AVANTCAR	Data and infrastructure provider	Provides data and access to the EV charging station fleet
EP	DSO	Provides part of the grid for testing WP5 innovations and shares grid-related data.
EL	DSO	Provides part of the grid for testing WP5 innovations and shares grid-related data.
ETRA	Technology provider	Provides the tools associated with several WP5 innovations, as well as NILM
ICCS	Technology provider	Provides the tools associated with several WP5 innovations

6.1.3 Installed and planned equipment overview

Table 6.2. SI pilot equipment overview

Equipment type	Description	Location	Installation status, date	Purpose
Temperature and humidity measurement (EP)	Equipment for measuring the temperature of the transformer housing and the environment, as well as air humidity, with an IoT gateway for transferring data to the database using MQTT	3 MV/LV transformer substations in Ajdovščina industrial zone	Planned – settings and testing of one demo kit (planned to finalize for November 2025)	Data input for short term advanced asset management innovation tool
Temperature and humidity measurement (EL)	Equipment for measuring the temperature of the transformer housing and the environment, as well as air humidity, with an IoT gateway for transferring data to the database using MQTT	10 MV/LV transformer stations in the Grosuplje rural area.	Part of substations already equipped with sensors. Plan to install additional sensors until the end of Nov 2025.	Data input for short term advanced asset management innovation tool

6.1.4 Feedback collection plan

Feedback in the Slovenian pilot will be collected from two main sources: end-users interacting with the NILM tool and internal project partners involved in the demonstrations. The objective is to assess both the user-facing impact of OPENTUNITY innovations and the internal technical/organizational aspects of the demonstrations.

End-user and stakeholder feedback

The only direct end-user interaction in the Slovenian pilot is through the NILM (non-intrusive load monitoring) tool. Households will receive disaggregated appliance-level consumption data in real-time and total daily/weekly/monthly consumption per appliance-level. Feedback will be collected to evaluate:

- Usability and readability of the tool interface,
- Perceived accuracy of disaggregation results (on larger appliances only (e.g. heat-pump, EV charging device),
- Overall satisfaction and value of the service,
- Broader views on flexibility acceptance in household environments (complemented by surveys such as the one already conducted by Amibit).

Table 6.3. SI pilot end-user feedback collection plan

What will be collected	Who is involved	Methods	Frequency	Use of input
Satisfaction with NILM tool features	Households using Reduxi HEMS with NILM	Surveys	At tool setup, after several weeks, then periodically	Improve tool design, refine algorithms, contribute to WP7 evaluation of user trust and replicability
Flexibility-related views	Households	Online survey	Once during demonstration	Identify barriers and motivations for future flexibility engagement

Internal partner feedback

Internal feedback will be collected in two layers:

1. **Among Slovenian pilot partners (UL, SETUP, AVANTCAR, Amibit):** Focused on ensuring data exchange and pipelines function correctly, monitoring demonstration activities, and discussing evaluation progress.
2. **Between Slovenian pilot partners and innovation technical leaders (Amibit, EL, EP with relevant WP4/WP5 leaders):** Focused on feedback about data needs, demonstration progress, and DSO perspectives on tools such as advanced asset management, state estimation, or short-term asset management.

Table 6.4. SI pilot internal feedback collection plan

What will be collected	Who is involved	Methods	Frequency	Use of input
Data pipeline reliability and integration status	UL, SETUP, AVANTCAR, Amibit	Monthly pilot calls	Monthly (continuous monitoring)	Ensure smooth data flow to SETUP, resolve errors quickly, adjust procedures
Demonstration progress and results	UL, SETUP, AVANTCAR, Amibit	Monthly pilot calls	Monthly	Refine execution of test cases, track milestones
DSO feedback on tools	Amibit, EL, EP, innovation leaders	Bilateral meetings	As needed	Adapt demonstrations to reflect operational realities, capture DSO requirements

6.1.5 User scenario assumptions and impacts

The main interaction with end-users in the Slovenian pilot is via the NILM innovation, integrated with Reduxi HEMS. End-users (households) will interact with the tool to monitor disaggregated appliance-level consumption and receive total daily/weekly/monthly consumption of their appliances. Feedback from users is essential to validate the accuracy of the disaggregation and even more importantly to assess the usability of the tool.

The table below summarises the assumptions, expected impacts, and engagement activities carried out so far.

Table 6.5. SI pilot user scenarios

Innovation/tool	Scenario description	Assumptions made	Expected effect if assumptions not met
NILM via Reduxi HEMS	Households use NILM to view disaggregated appliance consumption and total consumption per appliance	Users check the tool regularly, provide feedback on accuracy of disaggregation and usability/readability of the interface	Without sufficient feedback, validation of NILM accuracy and usability is limited, reducing the ability to demonstrate its value for end-users

So far, a citizen survey was carried out between May and June 2025 (62 valid responses) to gather initial insights into energy consumption behaviours, cost perceptions, and interest in EMS/NILM services. The results showed:

- **High interest in NILM-like functionalities** (real-time monitoring, disaggregation of appliances).
- **General awareness of energy management services** and willingness to use tools that improve transparency of household energy use.
- **Moderate concern about costs**, but not seen as the main driver for adoption; electrical energy represents only a small share of household budgets.

These findings support the assumption that households will interact with the NILM tool and provide feedback on usability and accuracy. However, the survey also suggests a potential risk: while users are curious, they may not remain consistently engaged unless the tool is intuitive and delivers tangible insights.

Connection to assumptions and effects

- If users provide feedback as assumed, the pilot will be able to validate NILM disaggregation accuracy and usability.
- If feedback is low, the demonstration risks being limited in its ability to show user-perceived value, weakening replicability analysis.

Actions to ensure assumptions are met

- Simplify the feedback process (e.g., short pop-up survey in the tool, or very short questionnaires).
- Provide clear and meaningful outputs (e.g., appliance labels, cost insights) to sustain engagement.
- Reinforce participation through regular updates or communication with recruited users, so they see the value of their involvement.

6.2 Deployment plan

Table 6.6. SI pilot deployment plan. The dashed red line represents the start of OPENTUNITY demonstrations.

Slovenian pilot site deployment	Jan 2023 - Jul 2024	2024					2025												2026
		Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
	M01-M19	M20	M21	M22	M23	M24	M25	M26	M27	M28	M29	M30	M31	M32	M33	M34	M35	M36	M37
Topology data provision (EL)		■	■	■	■	■	■	■											
Measurement data provision (EL)		■	■	■	■	■	■	■											
SCADA & AMI communication to innovation leaders established (EL)												■	■						
Additional sensors installation in HV/MV substation (transformer and ambient temperature, humidity) (EL)							■	■											
Topology data provision (EP)						■	■	■	■	■									
Measurement data provision (EP)						■	■	■	■	■									
SCADA & AMI communication to innovation leaders established (EP)												■	■						
MV/LV transformer temperature & humidity sensors purchase and installation												■	■	■	■	■			
Integration of AVANTCAR charging stations to SETUP platform	■																		
Integration of Reduxi HEMS systems to SETUP platform	■																		
Monitoring and control setup for selected AVANTCAR charging station for testing purposes										■	■	■							

6.3 Test cases, datasets and KPIs

6.3.1 Test cases

In the Slovenian pilot, 16 test cases will be demonstrated, their short descriptions are provided below and the full descriptions are included in Annex 1 (section 10.1.4).

Table 6.7. Summary of SI pilot's test cases

Category	Test case ID	Test case name
Horizontal	TC1.2.3	NILM identification ability (SI pilot)
	TC1.3.1	State estimation calculation (SI pilot)
	TC1.5.1	Long-term asset management for smart metering equipment (SI pilot)
	TC1.5.2	Short-term asset management for HV/MV and MV/LV transformers (SI pilot)
	TC1.6.2	Topology identification (SI pilot)
	TC1.7.1	Network planning tool to defer distribution network investments (SI pilot)
Pilot-specific	TC3.1.1	Validation of location-level forecast accuracy for EV fleet baseline consumption
	TC3.1.2	Validation of portfolio-level forecast accuracy for EV fleet baseline consumption
	TC3.1.3	Data collection reliability assessment for EV charging infrastructure
	TC3.2.1	Validation of household-level forecast accuracy for HEMS baseline
	TC3.2.2	Validation of portfolio-level forecast accuracy for HEMS baseline
	TC3.2.3	Data collection reliability assessment for HEMS portfolio
	TC3.3.1	Simulation-based validation of optimal selection algorithm
	TC3.3.2	Market selection optimization for flexibility provision
	TC3.3.3	EV charging station operation – day-ahead participation
	TC3.3.4	Reduxi HEMS tariff system economic optimization

TC1.2.3 NILM identification ability (SI pilot)

Short description: This test case evaluates the ability of the NILM (Non-Intrusive Load Monitoring) module to identify individual household loads using only smart meter data as input. Validation will be carried out by comparing NILM disaggregation results against submetering data from larger appliances (EV charger, heat pump, PV) and by collecting citizen feedback on accuracy and usefulness.

Main responsible partners:

- Amibit (data provider, Reduxi integration, citizen engagement)
- ETRA (NILM module developer and evaluator)

Involved assets & systems:

- Smart meters (P, Q data)
- Submetering sensors for larger appliances (EV charger, heat pump, PV)
- Reduxi smart home gateway for real-time data provision
- NILM module (developed by ETRA)

Environment: Hybrid. Real household data from Slovenian pilot participants is transmitted via Reduxi to the NILM module. Disaggregation results are validated both quantitatively (against submetering data) and qualitatively (through user surveys).

TC1.3.1 State estimation calculation (SI pilot)

Short description: This test case validates the ÉTER state estimation module for increasing observability in Slovenian distribution networks, particularly at LV level. The module integrates heterogeneous data sources (SCADA, AMI, weather data) to generate pseudo-measurements where real-time data is missing, and calculates power flows with confidence weighting. Results are compared with the Slovenian DSO's existing state estimation system and smart meter data to evaluate accuracy and reliability.

Main responsible partners:

- EL/EP (Grid Operator – data provider, validation of results)
- ETRA (technology provider – state estimation functionality)

Involved assets & systems:

- ÉTER platform with state estimation and topology representation
- SCADA system (P, Q, V, I measurements)
- AMI system (P, Q, V, I data at 15-min resolution)
- Slovenian state estimation system (for benchmarking)
- Weather forecast provider (OpenWeather)

Environment: Hybrid – historical and near real-time measurement data are processed by the ÉTER state estimation tool. Outputs are validated against external state estimation results and available smart meter data.

TC1.5.1 Long-term asset management for smart metering equipment (SI pilot)

Short description: This test case validates the long-term module of the Advanced Asset Management tool, which enables DSOs to perform end-of-life (EoL) assessments of smart meters, detect critical smart meters in the network, and predict expected failures per brand/model. Using historical smart meter data and installation records, the tool provides EoL curves, critical meter detection via machine learning, and geospatial visualization of substations. The goal is to support DSOs in planning meter replacements and prioritizing maintenance.

Main responsible partners:

- EL and EP (DSOs – users of the tool)
- ICCS (developer of the Advanced Asset Management tool)

Involved assets & systems:

- DSO smart meter data collection systems (AMI)
- DSO asset management systems (installation/replacement records)
- Advanced Asset Management tool (ICCS) hosted on server infrastructure
- SFTP interface for uploading historical and close to real time data
- Smart meter geodata (secondary substations)

Environment: Hybrid – real smart meter and asset data from Slovenian DSOs are processed by the Advanced Asset Management tool in a controlled IT environment, with results validated against actual network conditions.

TC1.5.2 Short-term asset management for HV/MV and MV/LV transformers (SI pilot)

Short description: This test case validates the short-term module of the advanced asset management tool for HV/MV transformers. The module performs top oil temperature anomaly detection and prediction, raising alarms when abnormal conditions are detected, presenting historical logs of alarms, and forecasting possible critical conditions with associated failure probabilities. The goal is to enable DSOs to improve transformer monitoring, anticipate risks, and support preventive maintenance decisions.

Main responsible partners:

- EP, EL (DSOs – users of the tool)
- ICCS (developer of the advanced asset management tool)

Involved assets & systems:

- HV/MV transformers equipped with online monitoring systems (OLMS)
- OLMS measurements (e.g., current, top oil temperature, ambient temperature)
- Advanced asset management tool (ICCS) with short-term module
- Server infrastructure hosting the tool and database

Environment: Hybrid – daily OLMS data from Slovenian DSOs is uploaded via SFTP and processed by the short-term module of the Advanced Asset Management tool. Results (anomaly detection, forecasts, and logs) are presented in a GUI combining real-time dashboards and historical analysis.

TC1.6.2 Topology identification (SI pilot)

Short description: This test case validates the ÉTER topology identification module, which aims to infer grid connectivity and line impedances from SCADA and AMI measurement data. Historical and real-time data (P, Q, V, I) are analysed to reconstruct the network topology using voltage correlation methods. The inferred topology is then compared with the ground truth provided by the DSO to evaluate accuracy.

Main responsible partners:

- EL/EP (Grid Operator – data provider, validation of results)
- ETRA (technology provider – topology identification module)

Involved assets & systems:

- ÉTER platform with topology identification functionality
- SCADA system (P, Q, V, I measurements)
- AMI system
- Data sharing via MQTT based protocol

Environment: Hybrid – anonymized historical measurements are processed by the ÉTER module to infer network topology, which is then validated against reference data from the DSO.

TC1.7.1 Network planning tool to defer distribution network investments (SI pilot)

Short description: This test case demonstrates the use of the Network Planning Tool to defer distribution network investments by identifying the most cost-effective mix of flexibility resources (RES, demand response, and storage). By optimizing these choices, the tool evaluates investment deferral options while ensuring reliability and system stability. The DSO compares the estimated time of investments for scenarios with and without flexibility to quantify benefits.

Main responsible partners:

- EP, EL (DSOs – users of the tool)

- ICCS (developer of the Network Planning Tool)

Involved assets & systems:

- Network Planning Tool (ICCS) with investment deferral module
- EP distribution network datasets (topology, demand, power factors, candidate upgrades)
- Server infrastructure hosting the tool and GUI interface

Environment: Hybrid – real Slovenian distribution network data is uploaded to the planning tool, which runs power flow and optimization analyses to evaluate investment deferral scenarios, with user-defined economic and flexibility parameters.

TC3.1.1 Validation of location-level forecast accuracy for EV fleet baseline consumption

Short description: This test case evaluates the accuracy of short-term baseline forecasts for EV charging demand aggregated at the location level (e.g., charging stations under the same transformer). Forecasts are generated automatically at fixed intervals using historical and real-time data and evaluated for two horizons (day-ahead and 1-hour ahead). The goal is to assess how well the models capture local charging patterns and how forecast accuracy varies with the number of charging stations, load profiles, and user behaviour at each location.

Main responsible partners:

- AVANTCAR (data provider)
- UL (forecast model developer)
- SETUP (evaluation support)

Involved assets & systems:

- AVANTCAR charging stations and backend infrastructure
- SETUP platform receiving measurement data and supporting evaluation
- UL platform hosting and running the forecasting models

Environment: Live (forecasts are generated using real data, the accuracy is then compared against real measurements)

TC3.1.2 Validation of portfolio-level forecast accuracy for EV fleet baseline consumption

Short description: Validates baseline forecast accuracy at the portfolio level for the aggregated EV fleet. Forecasts are evaluated across market-relevant horizons (day-ahead and intra-day) to assess suitability for participation in energy and balancing markets.

Main responsible partners:

- AVANTCAR (data provider)
- SETUP (model hosting and execution)
- UL (KPI definition and evaluation)

Involved assets & systems:

- AVANTCAR fleet of charging stations and backend system
- SETUP aggregator platform for model execution and forecast management

Environment: Live – forecasts generated from real aggregated fleet data and compared with actual portfolio consumption.

TC3.1.3 Data collection reliability assessment for EV charging infrastructure

Short description: Assesses reliability of EV charging data collection by monitoring data completeness, outages, and reporting consistency. Metrics include missing data points, outage durations, and station-level availability.

Main responsible partners:

- AVANTCAR (real-time and historical data provider)
- SETUP (monitoring and logging)

Involved assets & systems:

- AVANTCAR charging stations and backend infrastructure
- SETUP platform with monitoring and data logging functionality

Environment: Live – continuous monitoring of real EV charging data streams.

TC3.2.1 Validation of household-level forecast accuracy for HEMS baseline

Short description: This test case validates the forecast accuracy of household-level energy consumption and production profiles using Reduxi HEMS devices. Forecasts are generated for each channel (e.g., PV, heat pump, grid exchange) and compared against actual household data. The goal is to assess forecast performance across different household asset types.

Main responsible partners:

- Amibit (HEMS data provider)
- UL (forecast model developer)
- SETUP (evaluation support)

Involved assets & systems:

- Reduxi HEMS devices installed in households
- Amibit backend platform providing household-level data
- UL platform hosting forecasting models

Environment: Live – forecasts generated and validated using real household HEMS data.

TC3.2.2 Validation of portfolio-level forecast accuracy for HEMS baseline

Short description: This test case evaluates baseline forecast accuracy for the aggregated HEMS portfolio. Forecasts of total portfolio consumption are generated and validated against actual aggregated household demand. The objective is to assess whether aggregated HEMS forecasts are suitable for providing grid services and supporting market participation.

Main responsible partners:

- Amibit (HEMS data provider)
- UL (forecast model developer)
- SETUP (evaluation support)

Involved assets & systems:

- Reduxi HEMS devices installed in households
- Amibit backend platform providing household-level data
- UL platform hosting forecasting models

Environment: Live – forecasts based on aggregated household data compared with measured portfolio consumption.

TC3.2.3 Data collection reliability assessment for hems portfolio

Short description: This test case evaluates the reliability of data collection from Reduxi HEMS devices across the entire portfolio. It monitors data completeness, delays, outages, and reporting consistency per channel and household.

Main responsible partners:

- Amibit (HEMS data provider)
- UL (forecast model developer)
- SETUP (evaluation support)

Involved assets & systems:

- Reduxi HEMS devices installed in households
- Amibit backend platform supplying data streams

Environment: Live – monitoring of continuous HEMS data flows.

TC3.3.1 Simulation-based validation of optimal selection algorithm

Short description: This test case validates the operation of the aggregator's optimal selection algorithm in simulated scenarios. Simulated flexibility curves are combined with synthetic flexibility requests and asset constraints to stress-test the algorithm. The objective is to verify cost minimization performance while respecting technical and reliability constraints under different portfolio configurations.

Main responsible partners:

- UL (algorithm developer and scenario designer)
- SETUP (scenario validation and support)

Involved assets & systems:

- Optimal selection algorithm hosted by UL

Environment: Simulated – algorithm tested on synthetic flexibility requests and scenarios.

TC3.3.2 Market selection optimization for flexibility provision

Short description: This test case evaluates the market selection module of the aggregator platform by comparing expected revenues from day-ahead (DA) and TSO markets. The objective is to test whether the platform consistently selects the most profitable option given forecasted flexibility and price signals.

Main responsible partners:

- SETUP (market selection algorithm execution)
- AVANTCAR (flexibility data provider)
- UL (KPI evaluation)

Involved assets & systems:

- SETUP aggregator platform with market selection functionality

Environment: Simulated – market conditions generated using forecasted flexibility and price curves.

TC3.3.3 EV charging station operation – day-ahead participation

Short description: This test case demonstrates the operation of an EV charging station controlled according to cost-optimized schedules based on DA price forecasts. Results are compared to baseline immediate charging to assess potential cost savings.

Main responsible partners:

- AVANTCAR (charging station operation)
- SETUP (optimization engine and model hosting)
- UL (evaluation support)

Involved assets & systems:

- Selected EV charging station operated by AVANTCAR
- SETUP aggregator platform with price forecasting and optimization modules

Environment: Live – schedules deployed to real EVCS, monitored via AVANTCAR platform.

TC3.3.4 Reduxi HEMS tariff system economic optimization

Short description: This test case addresses the optimisation of household electricity costs within the framework of the Slovenian tariff scheme, which is determined by the maximum consumption power. Accordingly, the primary objective is to minimise peak power demand while preserving the comfort of end-users. The analysis is centred on a heat pump as the appliance of interest, without the integration of battery storage systems so as to avoid additional investment costs.

The optimisation procedure will be conducted in an offline setting, utilising real-world data. The proposed heat pump optimiser aims to determine an operating schedule that reduces electricity expenditure by lowering peak power consumption, while simultaneously maintaining indoor thermal comfort through stable temperature control. The performance of the optimisation will be evaluated against a baseline scenario without optimisation. The outcomes of this study will inform the development of the Reduxi embedded HVAC optimisation module.

Main responsible partners:

- Amibit (HEMS data provider and provider of optimizer method)

Involved assets & systems:

- Reduxi HEMS devices installed in households
- Amibit backend platform providing household-level data
- Amibit platform for optimizer models

Environment: Offline analysis of live household data

6.3.2 Datasets

Table 6.8. Datasets provided by SI pilot for test cases

Dataset ID	Dataset name
DS.SI.01	EV charging power
DS.SI.02	HEMS power data per channel
DS.SI.03	Market price forecasts
DS.SI.04	EV charging station metadata
DS.SI.05	HEMS channel metadata
DS.SI.06	Flexibility bid scenarios
DS.SI.07	Asset constraints and parameters
DS.SI.08	Tariff structure
DS.SI.09	Smart meter historical data
DS.SI.10	Geodata of the secondary substations
DS.SI.11	Smart meter SFTP data
DS.SI.12	Transformer historical monitoring data
DS.SI.13	Transformer monitoring data from OLMS
DS.SI.14	Load profile (power curves)
DS.SI.15	Substation power factor data (cosφ)

DS.SI.16	Information on the lines that will be considered for possible upgrade
DS.SI.17	Distribution network topology
DS.SI.18	Smart meter and submetering data
DS.SI.19	Electrical grid estimated measurements in Slovenian pilot

Table 6.9. SI pilot mapping datasets with test cases

	Test cases															
Datasets	1.2.3	1.3.1	1.5.1	1.5.2	1.6.2	1.7.1	3.1.1	3.1.2	3.1.3	3.2.1	3.2.2	3.2.3	3.3.1	3.3.2	3.3.3	3.3.4
DS.SI.01							X	X	X				X	X	X	
DS.SI.02										X	X	X	X			X
DS.SI.03														X	X	
DS.SI.04							X	X	X					X	X	
DS.SI.05										X	X	X				X
DS.SI.06													X			
DS.SI.07													X			
DS.SI.08																X
DS.SI.09			X													
DS.SI.10			X													
DS.SI.11			X													
DS.SI.12				X												
DS.SI.13				X												
DS.SI.14						X										
DS.SI.15						X										
DS.SI.16						X										
DS.SI.17						X										
DS.SI.18	X				X											
DS.SI.19		X			X											

6.3.3 KPIs

6.3.3.1 Summary and mapping of SI pilot KPIs

Table 6.10. Summary of updated SI pilot's KPIs

New KPI ID	Old KPI ID	Title	Action	Comment
KPI.SI.01	KPI_27	EV fleet baseline forecast accuracy	Updated	Modified to address the issue with small number of EVCS
-	KPI_28	EV fleet flexibility forecast	Removed	Deemed not feasible to evaluate accuracy, except for baseline
KPI.SI.02	KPI_29	HEMS fleet baseline forecast	Kept	-
-	KPI_30	HEMS flexibility forecast	Removed	Same as for old KPI_28
KPI.SI.03	KPI_31	Algorithm latency/calc. time	Kept	-
KPI.SI.04	KPI_32	Flexibility bid fulfilment rate	Updated	Renamed and modified to better reflect its purpose
KPI.SI.05	-	Average expected revenue	Added	For evaluating TC3.3.2
KPI.SI.06	-	Charging cost savings	Added	For evaluating TC3.3.3

KPI.SI.07	-	Tariff cost savings	Added	For evaluating TC3.3.4
KPI.SI.08	-	Data completeness rate	Added	For evaluating TC3.1.3 and TC3.2.3
KPI.AAM.01	KPI_06	Accuracy on asset condition	Kept	-
KPI.GPO.01	KPI_09	Investment deferral	Kept	-
KPI.GPO.02	KPI_18	Cost reduction due to deferral of grid upgrade	Updated	Corrected minor typos in the KPI description and updated the calculation steps
KPI.GPO.03	KPI_43	Decrease in investment costs	Updated	Corrected minor typos
KPI.NILM.01	KPI_02	NILM F1	Kept	-
KPI.SE.02	KPI_03	State estimation MAPE	Updated	Renamed and adapted to SE
KPI.TI.01	KPI_07	Topology identification MAPE	Updated	Changed metric from F1 score to MAPE

Table 6.11. SI pilot mapping KPIs with test cases

	Test cases																
KPIs		**1.2.3**	**1.3.1**	**1.5.1**	**1.5.2**	**1.6.2**	**1.7.1**	**3.1.1**	**3.1.2**	**3.1.3**	**3.2.1**	**3.2.2**	**3.2.3**	**3.3.1**	**3.3.2**	**3.3.3**	**3.3.4**
	KPI.SI.01							■	■								
	KPI.SI.02										■	■					
	KPI.SI.03													■			
	KPI.SI.04													■			
	KPI.SI.05														■		
	KPI.SI.06															■	
	KPI.SI.07																■
	KPI.SI.08									■			■				
	KPI.AAM.01			■	■												
	KPI.GPO.01						■										
	KPI.GPO.02						■										
	KPI.GPO.03						■										
	KPI.NILM.01	■															
	KPI.SE.02		■														
	KPI.TI.01					■											

Table 6.12. SI pilot mapping KPIs with strategic objectives

	KPIs															
Strategic objectives		**KP.SI.01**	**KPI.SI.02**	**KPI.SI.03**	**KPI.SI.04**	**KPI.SI.05**	**KPI.SI.06**	**KPI.SI.07**	**KPI.SI.08**	**KPI.AAM.01**	**KPI.GPO.01**	**KPI.GPO.02**	**KPI.GPO.03**	**KPI.NILM.01**	**KPI.SE.02**	**KPI.TI.01**
	SO1. Decarbonization of EU society	■	■	■							■		■	■	■	■
	SO2 Citizen and stakeholder empowerment						■							■		
	SO3 Ensure quality of supply in a context of increase of RES			■	■	■		■	■	■	■	■	■		■	■

6.3.3.2 Pilot site baseline overview

Each KPI related to the Slovenian pilot needs to be calculated after demonstrations and benchmarked with state-of-the art or business as usual (BAU) figures. We present here the baseline methodology selected for each KPI, with its value (or expected value) marked in **orange**. When OPENTUNITY innovation tools are expected to bring a relevant improvement, we also argue for our estimated target, marked in **red**.

KPI.SI.01 EV fleet baseline forecast accuracy

The baseline for this KPI is defined as the performance of a naïve day-ahead forecasting approach. In this scenario, the load in each 15-minute interval of the next day is assumed to be equal to the load observed in the same interval of the previous day (D-1 persistence). This provides a simple benchmark, since it does not require model training and relies only on historical profiles. At the **fleet (portfolio) level**, such naïve forecasts are expected to achieve WMAPE in the range of **~25–40%** based on preliminary results with Slovenian EV charging data from AVANTCAR during the test period in 2024 (between February and May). At the **location level**, where sites may include as few as 2–3 charging stations and load profiles are sparse with frequent zero-values, the error can be substantially higher. For these smaller sites, normalized MAE (nMAE, normalized by maximum capacity of the location) is used, with baseline error levels up to **~50%**.

KPI.SI.02 HEMS fleet baseline forecast accuracy

The baseline is defined using a naïve day-ahead forecast based on D-1 persistence. At the household (asset/channel) level, this means assuming that PV generation, heat pump consumption, or grid exchange for a given 15-minute interval on day D will equal the observed value at the same time on day D-1. At the portfolio level, the baseline corresponds to applying this same approach to the aggregated HEMS portfolio model. Preliminary tests suggest that **household-level** errors for individual channels typically yield WMAPE values of **~30%**, while **portfolio-level** forecasts are expected to perform better, with WMAPE closer to **15–20%.**

KPI.SI.03 Optimal selection algorithm latency

The baseline for this KPI is defined as a **response time of 30 seconds**, representing the maximum acceptable latency for flexibility activation processes. This threshold reflects the operational requirement for near real-time responsiveness in market participation and asset activation. The optimal selection algorithm should meet or improve upon this baseline to ensure timely decision-making.

KPI.SI.04 Optimal selection algorithm bid satisfaction rate

The baseline is defined as the performance of a random allocation strategy, where assets are selected randomly until the requested flexibility volume is met or until no more assets are available. This provides a lower-bound reference for how well requests can be satisfied without intelligent selection. Under such conditions, satisfaction rates are highly scenario-dependent: in cases where flexibility is abundant, fulfilment may reach 80–90%, while in tighter scenarios, random allocation may fall to 60% or below. For the purposes of this KPI, the indicative baseline satisfaction rate is expected in the range of **60–80%**.

KPI.SI.05 Average expected revenue

The baseline for this KPI is defined as **zero revenue**, corresponding to a situation where available flexibility is not used in any market. This provides a conservative benchmark representing the absence of participation. Any expected revenue above this baseline reflects the added value of enabling and optimizing market participation through the aggregator platform.

KPI.SI.06 Charging cost savings

The baseline for this KPI is defined as **zero cost savings**, corresponding to immediate full-power charging upon plug-in with no optimization. This reflects the standard, non-optimized behaviour of charging stations today, where charging costs are fully determined by prevailing day-ahead and intraday (DA/ID) prices at the time of connection. Any positive savings compared to this baseline demonstrate the effectiveness of optimized scheduling. Preliminary assessments suggest that applying an optimized charging schedule can reduce charging costs by **10–20%** compared to this baseline.

KPI.SI.07 Tariff cost savings

The baseline for this KPI is defined as **zero cost savings**, corresponding to normal household operation under the Slovenian tariff system without optimization. In this case, devices follow user preferences without shifting consumption to cheaper tariff blocks or avoiding peak penalties. Any observed savings compared to this baseline represent the added value of Reduxi HEMS tariff optimization. Cost savings compared to the baseline are expected in the range of **10–15%** depending on household load composition and tariff profile.

KPI.SI.08 Data completeness rate

The baseline for this KPI is defined as a minimum acceptable data completeness level of **85%**. This threshold represents the lower bound of reliability needed for forecasts and flexibility calculations to be considered trustworthy. If completeness falls below this level, the quality of derived forecasts and activation strategies may be significantly affected. Actual data completeness in the pilot will be tracked against this threshold during the demonstration.

KPI.AAM.01 Accuracy on asset condition

The KPI is defined as follows:

$$Accuracy = 100\frac{\sum_{i=1}^{N} I}{N}$$

Where:

- I: Binary equal to 1 if for asset *i* if the prediction condition category is the actual category provided by the DSO
- N: Number of samples

Since the OPENTUNITY advanced management tool is not applied yet, the baseline for this KPI is **0**.

KPI.GPO.01 Investment deferral

The KPI is defined as follows:

$$\Delta T = \mathrm{T}_{\mathrm{R\&I}} - \mathrm{T}_{\mathrm{base}}$$

Where:

- $\mathrm{T}_{\mathrm{base}}$: Time of investment in years, in the BAU scenario.
- $\mathrm{T}_{\mathrm{R\&I}}$: Time of investment in years, when flexibility is installed and optimized.

When the planning tool is not applied (i.e. baseline), $\mathrm{T_{R\&I}}$ will be equal to the BAU time $\mathrm{T_{base}}$. Thus, according to the aforementioned formula for the calculation of ΔT, the baseline for this KPI is **0**.

KPI.GPO.02 Cost reduction due to deferral of grid upgrade

The KPI is defined as follows:

$$Cost_{reduction} = \frac{Cost_{BAU} - Cost_{Flexibilty}}{Cost_{BAU}} \cdot 100$$

Where:

- $Cost_{reduction}$: Reinforcement cost when not upgrading the power grid due to utilization of the local flexibility market.
- $Cost_{BAU}$: Reinforcement cost in the BAU scenario.
- $Cost_{Flexibility}$: Grid reinforcement cost when considering the use of flexibility.

When the tool is not applied (i.e. baseline), $Cost_{BAU}$ will be equal to $Cost_{Flexibility}$. Thus, according to the abovementioned formula for the calculation of the $Cost_{reduction}$, the baseline for this KPI is **0**.

KPI.GPO.03 Decrease in investment costs

The KPI is defined as follows:

$$\Delta P_{RES} = 100 \frac{\mathrm{C}_{BAU} - C_{\mathrm{R\&I}}}{\mathrm{C}_{BAU}}$$

Where:

- $C_{\mathrm{R\&I}}$: Cost of network upgrades estimated in the pilot with optimal scheduling of flexibility and network investments.
- C_{BAU}: Cost of network upgrades estimated with existing methodologies applied in each pilot.

When the planning tool is not applied (i.e. baseline), $C_{\mathrm{R\&I}}$ will be equal to the cost of BAU scenario, C_{BAU}. Thus, according to the abovementioned formula for the calculation of ΔP_{RES}, the baseline for this KPI is **0**.

KPI.NILM.01 NILM F1

Currently, there is no method for disaggregating energy consumption data in place in the pilots, so the project is providing a new service that opens the door to new impacts. In terms of technical performance, there are Spanish grid utilities that have their own disaggregation methods and reach 80% of accuracy. Considering this value and to further improve the performance, the baseline for OPENTUNITY has been set to **80%**. F1 score, which considers the accuracy, precision and recall of the classes to predict (ON and OFF detections) calculated in this KPI could be increased in the project to **at least 85% on average**, considering each appliance monitored.

KPI.SE.02 State estimation MAPE

The performance of state estimation algorithms depends on the observability of the grid and the real measurements available. However, research estimates the errors as follows:

- **Voltage: ±2%**
- **Angle: ±5%**
- **Power flows: ±10%**
- **Loads: ±10%**

OPENTUNITY techniques are expected to leverage Physic Informed Neural Networks (PINNs) to ensure keeping the MAPE lower than these thresholds (the target is to **lower them by ~50%**).

KPI.TI.01 Topology identification MAPE

There is currently no topology identification algorithm deployed in any pilot to compare with. Nevertheless, state-of-the-art in the field accounts for an accuracy of **60%**. Our goal is to enhance this level but calculating the MAPE, our target being **MAPE <40%**.

6.4 Demonstration plan

Table 6.13. SI pilot demonstration plan. The dashed red lines represent the start and end of OPENTUNITY demonstrations.

Slovenian pilot demonstration plan	2025					2026							
	Jan 2023 - Aug 2025	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
	M01-M32	M33	M34	M35	M36	M37	M38	M39	M40	M41	M42	M43	M44
TC1.2.3 NILM identification ability													
Identify Reduxi HEMS systems participating in NILM demonstration													
Reduxi data integration to NILM tool													
Models training													
Models testing period 1 - Winter													
Models testing period 2 - Spring													
KPI evaluation and analysis													
Final algorithm evaluation													
TC1.3.1 State estimation calculation													
EL/EP data integration with ETRA													
Model training													
Testing period, data and feedback collection													
KPI evaluation and analysis													
TC1.5.1 Long term asset management for smart metering equipment													
ICCS's integration with pilot's data and data sources													
Models training													
Deployment and integration of ICCS long-term asset management tool													
Tool testing and performance review													
KPI evaluation and analysis													
TC1.5.2 Short term asset management for HV/MV and MV/LV transformers													
Integration of pilot's data and data sources													
Models training													
Deployment/Integration of ICCS short-term asset management tool													
Tool testing and performance review													
KPI evaluation and analysis													
TC1.6.2 Topology identification													
EL/EP data integration with ETRA													
Model training													
Testing period, data and feedback collection													
KPI evaluation and analysis													
TC1.7.1 Network planning tool to defer distribution network investments													
Integration of pilot's data and data sources													
Deployment/Integration of ICCS network planning tool													
Tool testing and performance review													
KPI evaluation and analysis													
TC3.1.1 Validation of location-level forecast accuracy for EV fleet baseline consumption													

Setup the monitoring dashboard (visualization, KPI calculation)
Model training and deployment
Model testing period
KPI evaluation and analysis
TC3.1.2 Validation of portfolio-level forecast accuracy for EV fleet baseline consumption
Setup the monitoring dashboard (visualization, KPI calculation)
Model training and deployment
Model testing period
KPI evaluation and analysis
TC3.1.3 Data collection reliability assessment for EV charging infrastructure
Setup the monitoring procedure
Monitoring period
KPI evaluation and analysis
TC3.2.1 Validation of household-level forecast accuracy for HEMS baseline
Setup the monitoring dashboard (visualization, KPI calculation)
Model training and deployment
Model testing period
KPI evaluation and analysis
TC3.2.2 Validation of portfolio-level forecast accuracy for HEMS baseline
Setup the monitoring dashboard (visualization, KPI calculation)
Model training and deployment
Model testing period
KPI evaluation and analysis
TC3.2.3 Data collection reliability assessment for HEMS portfolio
Setup the monitoring procedure
Monitoring period
KPI evaluation and analysis
TC3.3.1 Simulation-based validation of optimal selection algorithm
Define synthetic flexibility request scenarios, prepare baseline curves based on real data
Run simulations of different scenarios and configurations
Collect and process outputs, calculate KPIs
Final evaluation and analysis of the algorithm
TC3.3.2 Market selection optimization for flexibility provision
Market selection module deployment
Historic DA/TSO prices collection, setup connection to EV fleet forecasting module
Daily simulation runs
KPI calculation and analysis
TC3.3.3 EV charging station operation – day-ahead participation
Finalize preparation for analyzed EVCS, ensure communication with AVANTCAR is stable
Demonstration period, SETUP sends daily optimized schedule, data collection
KPI calculation and analysis
TC3.3.4 Reduxi HEMS tariff system economic optimization
Models training
Testing period
KPI calculation and analysis

6.5 Risk management plan

Table 6.14. SI pilot risk management plan

Risk ID	Risk description	Category	Likelihood	Impact	Mitigation/contingency action
SI.01	Delay in installation of temperature sensors at EP and EL pilot sites due to slow coordination between departments (installation, communication, data storage).	Organizational	Medium	Medium/High	UL (pilot leader) to actively assist and push coordination between responsible departments to ensure timely installation and data integration.
SI.03	Lower-than-expected number of households adopting Reduxi NILM devices (fewer survey respondents willing to participate).	User-related	Medium	Medium	Increase recruitment efforts (wider reach, more direct communication), consider using existing Reduxi users (e.g., company employees) to secure sufficient data.
SI.03	API connection failure between AVANTCAR backend and SETUP platform, causing data interruptions or corrupted inputs.	Technical/Data	Low-Medium	Medium	Short-term interruptions handled by data interpolation; in case of longer outages, issue raised immediately with partners to restore communication and ensure data continuity.
SI.04	Metering point connection failure at Avantcar Peca charging point (contractual agreement for electricity supply)	Technical/Data	Low-Medium	Medium/High	AVANTCAR and SETUP regularly communicate with EL to ensure priority on maintaining an intact communication of the metering point as it is extremely important for the test cases.
SI.05	User's cooperation in NILM analysis might be too low for proper analysis of the data	User-related	Medium	Medium	To mitigate low cooperation of the users in the NILM analysis, the software has to be very direct and user-friendly. We have to continuously monitor the end-users' involvement and adjust the software accordingly.
SI.06	HEMS tariff optimization suitability to real-life scenario	Technical	Medium	Medium	The analysis will be done offline with the final goal to transfer the results to real built-in algorithms. The risk might be in the estimation of house temperature inertia. To mitigate the risk, the analysis will be performed on several thermal time constants.

7 Demonstration phase monitoring and evaluation framework

This section defines the common framework for monitoring, evaluating, and comparing the pilot demonstrations in OPENTUNITY. It ensures that activities across pilots are tracked in a consistent way, that issues are identified early, and that comparable results are generated for cross-pilot analysis. The framework also provides the link between the present deliverable (D6.1) and the upcoming reporting of demonstration results in D6.2, and further evaluation and replication activities in WP7.

7.1 Monitoring of demonstration activities

The deployment and demonstration phase officially started in December 2024 (M24) and will run until June 2026 (M42). Deployment activities are just about to finish at the publication of this deliverable (M34), which coincides with the start of demonstrations for all pilots. The activities performed in this first phase of D6.1 preparation lay the foundation for systematic monitoring of all pilot site demonstrations.

Monitoring will be performed through a combination of:

- **Monthly WP6 coordination calls** (Microsoft Teams):
    - Pilot partners present updates on their demonstration progress, including milestones achieved, barriers encountered, and next steps.
    - Issues are discussed collectively, and mitigation actions are defined to ensure timely resolution.
- **Dataset monitoring**:
    - A dedicated tracking document will be created, based on the dataset list defined for each pilot.
    - This document will be used to monitor the status, availability, and quality of datasets during the demonstration.
    - Any missing or incomplete datasets will be flagged early, enabling corrective measures.
- **Internal feedback loops**:
    - Continuous partner feedback (technical and organizational) will be collected alongside demonstration progress, ensuring smooth demonstration activities
- **Dedicated reporting documentation**:
    - A structured reporting template will be established to allow pilot partners to record their testing progress, observations, and preliminary results as demonstrations unfold.
    - This will ensure that relevant information for Deliverable D6.2 is gathered continuously, allowing for real-time tracking of pilot activities and easier consolidation of results at the end of the demonstration phase.

The results of the demonstration activities will be reported in D6.2, including:

- Quantitative results: performance metrics (KPIs) for each test case.
- Qualitative analysis: contextual insights, user/stakeholder perspectives, and lessons learned.

These results will also feed into WP7, where they will be evaluated in detail and used to assess replication potential in other regions and contexts.

7.2 Trust issues

7.2.1 Introduction

A central objective for the OPENTUNITY project has been to identify barriers and enablers for the adoption of flexibility services as perceived by stakeholders, **particularly end-consumers**. Within this context, trust emerges as a crucial – although often overshadowed – factor. Recognizing its importance, this aspect has been incorporated into the current deliverable and will also be touched upon in the upcoming deliverable D6.2 (pilot activities) and as part of Task 7.2 (impact assessment) and Task 7.4 (policy recommendations).

As OPENTUNITY integrates digital tools, flexibility services, and non-intrusive load monitoring to optimize energy consumption, ensuring that users feel confident about the platform's reliability, data security, and transparency is crucial. This chapter outlines how trust is approached within OPENTUNITY, drawing on both the general project framework and practical insights from pilot implementations across Europe.

7.2.2 General approach to trust in OPENTUNITY

OPENTUNITY embeds trust as a multi-dimensional concept encompassing transparency, user control, and data protection:

- **Transparency:** Users are informed in every project step and as openly as possible about what data is collected, how it is used, and which services it supports. OPENTUNITY emphasizes clear communication of its recommendations, and the rationale behind flexibility or energy optimization actions.
- **User control:** OPENTUNITY aims at offering as much control as possible in the hands of the end-consumer. For example, users can decide which appliances or data streams are monitored or shared, and adjust flexibility offers according to personal preferences. They can also set specific values that are not exceeded or fallen short of when optimising consumption to ensure maximum comfort at any given time. Users always have the possibility to override the control of their assets, should they feel that their comfort level is not met. On the other hand, the whole process of flexibility extraction (i.e., flexibility evaluation, bidding, bid acceptance and actual control of assets) is fully automated. Therefore, the end-consumer is not bothered with unwanted notifications or needed actions and can benefit from the developed tools effortlessly.
- **Data protection:** Compliance with EU General Data Protection Regulation (GDPR) is ensured across all pilots. Data is anonymized or pseudonymized where possible, and secure storage and transfer protocols are implemented to prevent unauthorized access.
- **Non-intrusiveness:** Especially in the case of load monitoring and energy consumption tracking, OPENTUNITY ensures minimal intrusion into users' daily routines. The design prioritizes ease of use, avoiding unnecessary interventions or notifications.

This general framework aims to foster trust not only during pilot phases but also as a foundation for broader deployment.

7.2.3 Insights from interactions

Apart from the general framework, we also aim at gaining insights from end-users themselves to get further ideas on how we can optimise the tool-development to further increase trust and user-satisfaction. To do so, we conducted data collections on the issue in all pilots and beyond. The concrete approach as well as the results (as far as they are already there) are explained below.

7.2.4 LinkedIn expert survey

To get first insights into consumer aspects of using load monitoring and energy management systems, we performed an expert survey via LinkedIn channels of OPENTUNITY and the project members. The survey explored consumer trust and engagement in the energy transition by addressing a range of interlinked themes. Respondents were asked about the level of consumer familiarity with concepts such as demand-side flexibility and whether the general public recognizes their potential role in energy markets. The survey further examined what would most motivate consumers to participate actively, while also identifying the main barriers that may prevent them from engaging in initiatives such as OPENTUNITY. A central focus was placed on transparency and trust, particularly regarding how important it is for energy providers to communicate openly about their sustainability practices and energy sources, and which factors consumers consider most decisive when choosing an energy provider.

A maximum of ten experts responded to each question. The survey results highlight both opportunities and trust-related challenges in engaging consumers with the energy transition. While a majority (60%) of respondents believe consumers are already very familiar with the concept of demand-side flexibility, a significant 40% see no familiarity at all. It seems that even experts themselves are not sure about this aspect, highlighting that implementation of new energy technologies should always be accompanied by communication strategies to learn more about the target audience and understand their knowledge level and skills.

Motivation is strongly tied to financial trust, with 78% stating that reducing energy bills is the main driver for engagement, far outweighing sustainability or technology-related incentives (Figure 8).

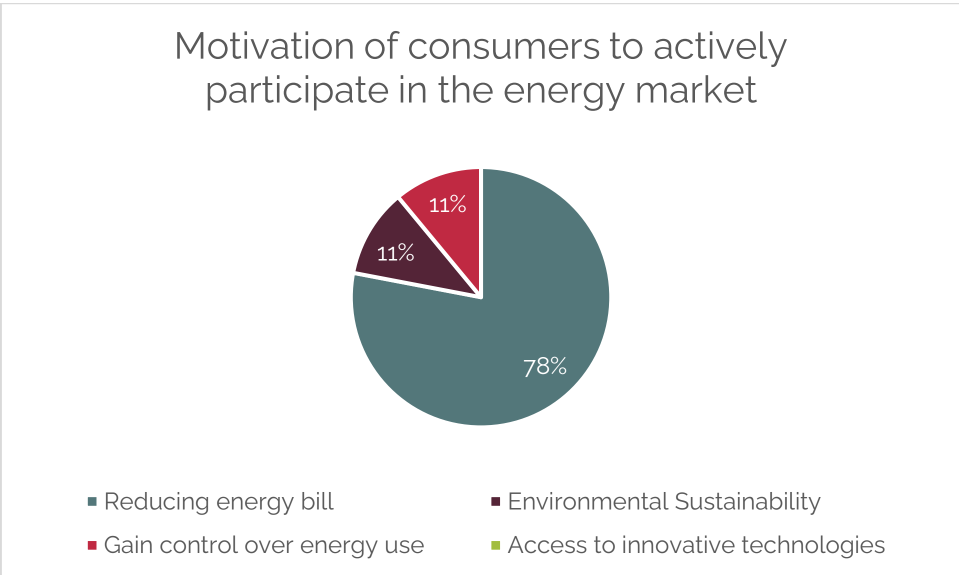


Figure 8. Expert opinion on consumers motivation to actively participate in energy markets (N=9)

Trust in transparency emerged as a central factor: 70% of respondents consider it extremely important that energy providers are open about their sustainability practices and energy sources, while the remaining 30% still rated it as important. Similarly, when asked about decision factors in choosing an energy provider, cost dominated (80%), but trust in customer service (20%) still outweighed sustainability commitments or innovation. This underlines the importance of reliability and especially openness over promises of future-oriented benefits. Exaggerated potential gains should therefore be avoided not to awake unrealistic expectations.

Barriers to engagement are mainly linked to complexity and trust in information. Half of the respondents see technological complexity as the biggest obstacle, while another quarter point to a lack of information and uncertainty about benefits. This is echoed in perceptions of market accessibility: 50% believe energy markets are too complicated for average consumers, and another 50% acknowledge complexity but note that consumers are learning to navigate it. Awareness is low—43% believe almost nobody knows about opportunities to actively participate, and another 43% say only a minority does. This points to a gap in both knowledge and trust that consumers can genuinely benefit.

Social trust plays a moderate but important role: 80% consider friends and family moderately impactful in energy-related decisions, with 20% seeing them as very impactful.

Overall, the findings suggest that building trust through transparency, clear communication, and reducing complexity is key to unlocking consumer participation in the energy transition. Cost savings are the primary motivator, but trust in providers, social networks, and easy-to-use technologies strongly shape the willingness to engage.

7.2.5 Slovenian pilot

Household end-consumer survey

In Slovenia, we conducted a household survey exploring electricity use, production, and perceptions of new energy management technologies. While the survey touched on issues such as appliance ownership, electricity prices, and cost concerns, a central theme was trust: How willing are households to share and monitor their data? How much confidence do they place in automated systems like Reduxi? And what role do privacy, data security, and perceived control play in their decision-making?

The results show that trust matters – but it is not the decisive barrier. Among the 64 valid responses collected between May and June 2025, only 10% of those not interested in real-time consumption tools cited distrust as a reason (Figure 9). Instead, most respondents were more concerned about practical aspects, such as the necessity, usability, or perceived benefits of such systems.

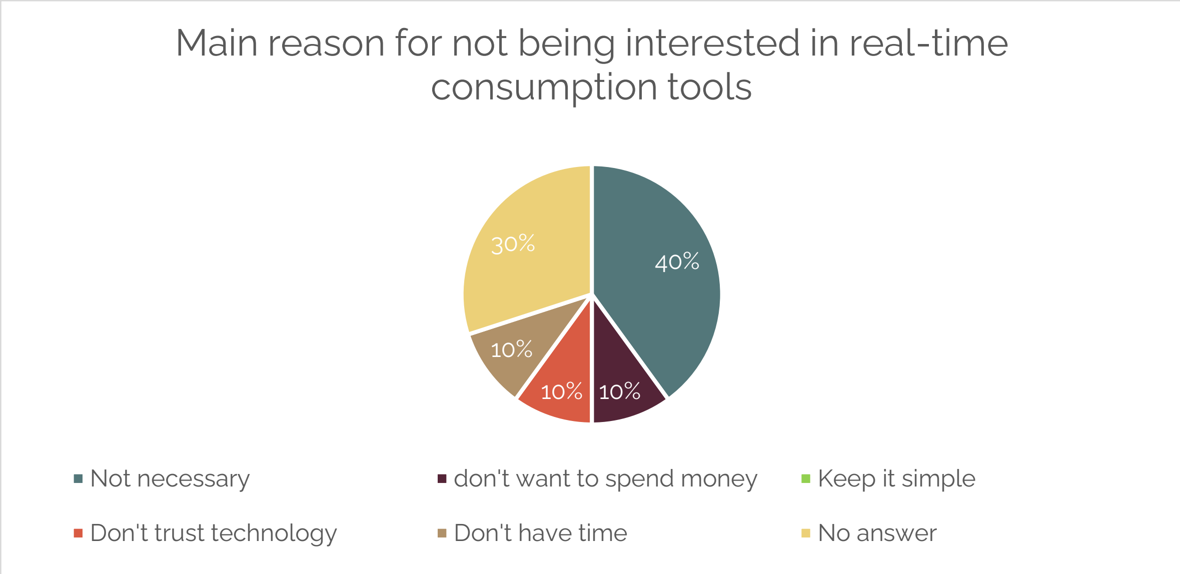


Figure 9. Reasons for not using real-time consumption tools in Slovenian survey (N=10)

This suggests that trust, while relevant, is not the primary issue. When asked about detailed monitoring (e.g., knowing which appliances consume the most energy), the responses again highlight that usability and convenience are more decisive than trust alone. Only 10% rejected the idea entirely, while the majority saw value if the system was easy to use or targeted high-consumption appliances. Trust becomes more visible in the context of HEMS. Here, 36% of respondents expressed concerns about privacy and data security, while 22% explicitly reported not trusting automated systems. However, these numbers are outweighed by other concerns: 39% named low usability as a barrier, 33% uncertainty about cost savings, and 27% the fear of losing comfort. Thus, although trust plays a role, it is not the dominant deciding factor. Asking the other way around, encouraging adoption seems most effective when focusing on tangible benefits and simplicity: 80% want clear cost savings, 61% favour ease of use, and 56% value maintaining control. Only 27% emphasize strong guarantees of privacy and security as a decisive incentive.

So, we can conclude, that, while trust is clearly a factor in the adoption of energy management systems but is not the central obstacle. **Practical concerns, especially cost savings, usability, and comfort, outweigh trust issues**. Trust can be strengthened through transparent communication and privacy guarantees, but the main driver of acceptance will be clear economic and practical advantages, paired with systems that are simple to use.

Electric car rental survey (Planned)

As a second measure to better understand the end-consumer and potential enablers and barriers of using flexibility services, we did a survey with Electric Car Rental users. The survey explores customer attitudes toward different EV-charging service models and tariff structures by presenting them with specific use-case scenarios (home charging, dedicated station charging, company site charging, and private EV home charging). Each use-case begins with a baseline interest question, followed by conditional sub-questions that dig deeper into the motivations, requirements, or reservations depending on the respondent's initial choice.

In relation to trust, the survey derives insights by including answer options that explicitly reflect customer concerns about risk, transparency, and control. For example, respondents are asked whether they fear hidden costs, worry about AVANTCAR accessing their electricity consumption data, or are concerned about potential technical harms such as power surges. Similarly, conditions such as requiring AVANTCAR to install and service the charging infrastructure at no cost, or to guarantee liability coverage, highlight where trust in the provider's reliability, fairness, and accountability is being tested. By mapping the frequency and intensity of such responses, the survey provides a structured way to identify where trust is fragile and which assurances or safeguards would be most effective in building user confidence. The survey was distributed to all AVANT car members on Friday 26th of September 2025 with the primary aim to explore which potential business models are most relevant for future EV users with regards to flexibility services. Secondly, we will also derive what aspects of trust are most important to tackle to ensure a smooth adoption of these services.

7.2.6 Spanish pilot

Push and pull factors from potential users

In the Spanish pilot, feedback was collected from willing people who showed interest in the project, as part of the survey for registering as a participant. Questions here were less focussed on trust, but more strongly on receiving general feedback on the presented tools (asking about communication, knowledge gain, expectations towards the use of the tools, etc.). 14 people filled out the survey (Figure 10).

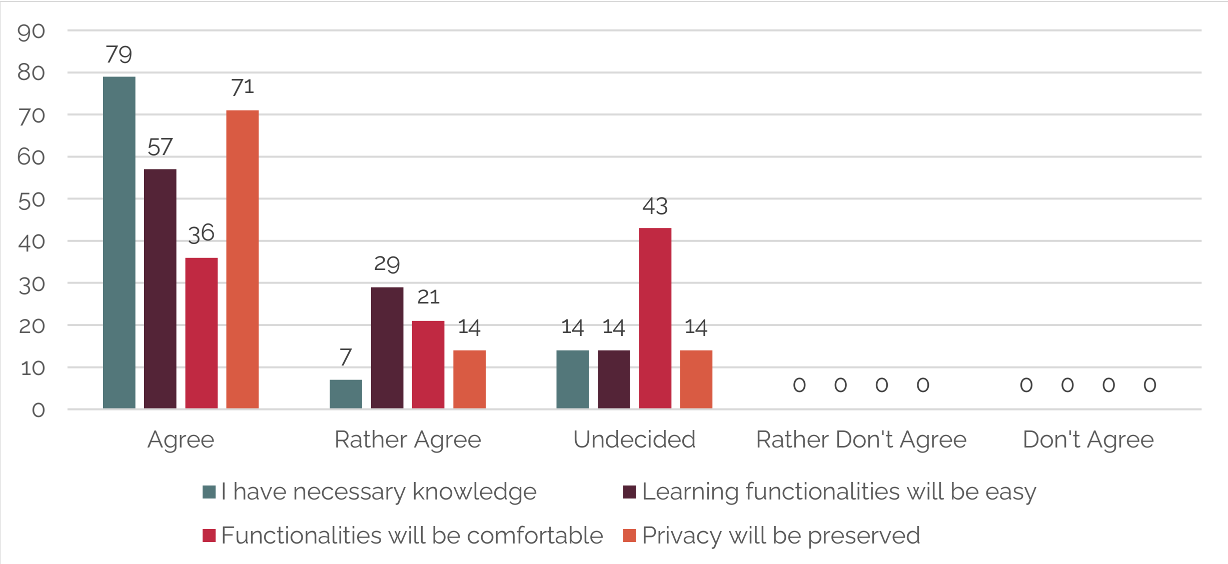


Figure 10. Opinions on using OPENTUNITY tools in Spanish survey (N=14)

Generally, they found the team's presentation very positive (i.e. 93% fully or rather agree that the benefits are explained clearly) and trust that they have the necessary knowledge (86% fully or rather agree) and can easily learn the provided functionalities (86% fully or rather agree). This leads to the result that 93% fully or rather agree to use the tools regularly in the future. This might also be insured by the fact that also 86% fully or rather agree that their privacy will be protected during their participation in the project, pointing towards the direction that trust is an aspect that should be covered by the developed tools.

7.2.7 Greek pilot

End-user survey

In the Greek pilot, the household survey mirrored the approach taken for Slovenia (also to allow for cross-country comparison). We targeted all people that registered to the Greek online platform to receive more information about OPENTUNITY and possibilities to become part.

7.2.8 Swiss pilot

Maintenance Manager Interviews

In Switzerland, OPENTUNITY chose another approach and did not interact with end-consumers directly. Instead, the OPENTUNITY tools are used in community buildings and condominiums. Therefore, instead of a survey, interviews are performed to gather feedback. The interviews are designed to explore the experiences, perceptions, and expectations of building's staff regarding the installation and operation of OPENTUNITY energy systems, with a particular focus on trust. It begins by capturing the interviewee's profile, including role, experience, and prior exposure to energy or automation systems, which helps contextualize their confidence in and understanding of the new technology. Then, general awareness and expectations are discussed, examining when the interviewee first learned about the systems, next the installation process is explored, asking participants to reflect on the smoothness of installation, consultation, and any challenges encountered. Feeling informed and consulted during installation fosters trust, while unanticipated disruptions or lack of clarity can undermine confidence. Similarly, the maintenance and operation section explores the interviewee's role, frequency of interaction, training received, and experiences resolving technical issues. Trust is supported when staff feel competent, have access to clear instructions, and can rely on responsive support channels. Concerns, fears, and pain points are explicitly addressed, with questions targeting perceived changes in responsibilities, potential negative effects, and the sense of involvement. These insights highlight areas where trust may be weakened and where better communication or support could reinforce it. Perceived benefits, improvements, and desired enhancements are then explored, as tangible positive outcomes and opportunities for feedback further strengthen confidence in the systems. The interviews were performed in September and October 2025.

7.2.9 Key takeaways on trust

Across the expert survey and pilot activities, trust emerges as a necessary but not sufficient condition for consumer engagement in energy initiatives. Several key insights stand out:

- **Transparency and openness are essential**: Both the expert survey and pilot activities confirm that consumers expect providers to be clear about potential cost-savings, sustainability practices, energy sources, and data handling. Trust is damaged when communication is vague, overly complex, or when benefits appear exaggerated.
- **Trust alone does not drive adoption**: In Slovenia, distrust in monitoring tools or automated systems was mentioned, but practical concerns (cost savings, usability, and maintaining comfort) were far stronger barriers.

- **Complexity undermines confidence**: Half of the experts see technological complexity as a major barrier, and many end-users worry about usability. If systems are not intuitive, trust in their value and reliability decreases.
- **Social trust plays a supportive role**: Friends, family, and local communities moderately shape energy-related decisions. This suggests that peer-to-peer trust and word-of-mouth can amplify adoption once early users report positive experiences.

Inclusion in OPENTUNITY tools and designs

- OPENTUNITY tools offer user-friendly and interactive interfaces that support strategic and informed decisions by system operators. The UIs are designed to ensure accessibility and usability in real-world applications, enabling efficient and effective user interaction with minimal complexity in execution.
- The OPENTUNITY NILM tool has been developed with a strong focus on usability and transparency. Built using JavaScript and React, it offers a clean and responsive user interface. Data visualisations are implemented through the Recharts library, ensuring information is presented in a clear and intuitive way. This approach allows households to easily interpret their energy data
- The OPENTUNITY team favours clear communication all the time: Cost benefits are clearly shown, but also no exaggerated expectations are raised. Data visualisations are transparent, and easily understandable to show households the immediate value of adoption.
- Households can decide which appliances are monitored or controlled, ensuring they feel in charge rather than managed by the system.
- Even if trust is not the main barrier, the high security of the system is emphasised, and the data handling is communicated transparently.

8 Conclusions

This deliverable contains all the preparatory work performed between M24 and M34 of OPENTUNITY project for the demonstrations that will take place between M34 and M42. It consolidates the methodological, organizational, and technical foundations required for the pilot activities, ensuring a harmonized and traceable approach across all four pilot sites.

The document includes comprehensive pilot site characterizations, outlining the infrastructures, partners, and user groups involved in the demonstrations. For each pilot, deployment and demonstration plans have been developed together with detailed test cases, associated datasets, and KPIs, all of which are compiled and cross-referenced in the Annex. In total, 53 pilot-specific test cases and four cross-platform test cases have been defined, covering the spectrum of OPENTUNITY innovations. These test cases are directly linked with the project's strategic objectives and form the basis for the evaluation activities in WP7.

In addition to the technical and methodological framework, the deliverable also addresses risk management, monitoring, and feedback collection mechanisms to ensure robust execution and transparent evaluation of the demonstration phase. A dedicated chapter focuses on user trust and acceptance of OPENTUNITY innovation tools. Trust emerges as a crucial, though often underestimated, factor influencing the adoption of flexibility services. The project therefore places strong emphasis on understanding and enhancing user confidence, recognizing trust as a cornerstone for the successful deployment and uptake of OPENTUNITY solutions.

The next phase of Task 6.1 will focus on executing the planned test cases, monitoring pilot activities, and calculating the KPIs defined in this document. The outcomes of these activities will be presented in Deliverable D6.2 (due Month 42) and will directly support the evaluation work conducted under WP7. Further insights into user engagement and trust will also be developed in coordination with WP7 deliverables, ensuring continuity between the demonstration and evaluation phases of OPENTUNITY.

9 References and acronyms

9.1 References

[1] OPENTUNITY, "D2.1 Technical foundations," 2023.

[2] OPENTUNITY, "D1.1 Project Management Plan," 2023.

[3] OPENTUNITY, "D5.4 OPENTUNITY asset and planning developments (v2)," 2025.

[4] OPENTUNITY, "D5.1 OPENTUNITY power flow developments (v1)," 2024.

9.2 Acronyms

Table 9.1: List of acronyms used in the deliverable

Acronym	Meaning
AAM	Advanced Asset Management
AMI	Advanced Metering Infrastructure
AMR	Automatic Meter Reading
API	Application Programming Interface
AVDI	Average Voltage Deviation Index
BAU	Business As Usual
BFMS	Building Flexibility Management System
CIM	Common Information Model
CIS	Customer Information System
DA	Day-Ahead
DB	Database
DER	Distributed Energy Resource
DGA	Dissolved Gas Analysis
DLR	Dynamic Line Rating
DNN	Deep Neural Network
DPP	Digital Product Passport
DR	Demand Response
DRTTR	Dynamic Real-Time Thermal Rating
DS	Dataset
DSO	Distribution System Operator
DSP	Data SPace
DSSE	Distribution System State Estimation
EHV	Extra High Voltage
EMS	Energy Management System
EO	Economic Operator
EoL	End of Life
ESCO	Energy Service Company
EV	Electric Vehicle
EVCS	Electric Vehicle Charging Station
FM	Flexibility Market
FMO	Flexibility Market Operator
FSP	Flexibility Service Provider
GDPR	General Data Protection Regulation
GHG	GreenHouse Gas
GPO	Grid Planning Optimization

GUI	Graphical User Interface
HEMS	Home Energy Management System
HL-UC	High-Level Use Case
HV	High-Voltage
ID	Intraday
IdM	ID Management
IoT	Internet of Things
ISP	Integrated Scheduling Process
KPI	Key Performance Indicator
LFM	Local Flexibility Market
LV	Low-Voltage
MAPE	Mean Absolute Percentage Error
MC-MAPE	Measurement-Consistent Mean Absolute Percentage Error
MV	Medium-Voltage
nMAE	Normalized Mean Absolute Error
NILM	Non-Intrusive Load Monitoring
OLMS	On-Line Monitoring System
PINN	Physic Informed Neural Network
PLC	Power-Line Communication
PMU	Phasor Measurement Unit
POD	Point Of Delivery
PV	Photovoltaics
R&D	Research and Development
RES	Renewable Energy Source
RID	Random ID
RT	Real-Time
RTTR	Real-Time Thermal Rating
SCADA	Supervisory Control And Data Acquisition
SE	State Estimation
SFTP	Secure File Transfer Protocol
SGIM	Smart Grid Interface Module
SO	Strategic Objective
SoC	State of Charge
STR	Static Thermal Rating
T&H	Temperature and Humidity
TC	Test Case
TFP	Type of Flexibility Provider
TI	Topology Identification
TMA	Topology Match Accuracy
TSO	Transmission System Operator
UC	Use Case
UHV	Ultra-High Voltage
UI	User Interface
WMAPE	Weighted Mean Absolute Percentage Error
WP	Work Package

10 Annex

10.1 Annex 1: Test cases

10.1.1 Greek pilot site test cases

GR pilot TC1.2.4

Test case ID	TC1.2.4
Name	NILM identification ability (GR pilot)
Timeframe	M34-M42
Targets	Analyze the ability of the NILM module to identify the different loads of a households using just the RT smart meter data as an input
Actors involved	• **ICCS**: Provides the consumption data from Greek pilot • **ETRA**: NILM developer
Assets & systems involved	• Smart meter • Consumption sensors • Smart home gateway • NILM module
Triggering event	The ESCO or the retailer aims to provide new features to their clients, offering them the possibility to know their disaggregated consumption per asset without need of submetering.
Pre-condition	• A small batch of households with submetering are available to validate the results of NILM • Assets installed in each household are known
Test case description	Before the own execution of the test, the pilot site and ETRA must agree on the timeframe of the test. It has been agreed in a week in December and a week in May in order to analyse the results covering workdays, weekends and cold and hot weathers. Then: • The smart home gateway must send the data from the smart meter to the NILM module during the defined periods. It should also store the data from the sensors. • The NILM module will be running and storing the RT data coming from the smart home gateway of the analysed period. After each period • The smart home gateway must send the data stored from the sensors to ETRA, • Then, it will be possible to compare the disaggregation coming from the NILM and the data from the sensors and calculate the precision, the recall and the F1 score of the results. The testing in four different pilot sites will also allow to get insights about whether the different identification ability is similar or different between pilot sites and analyzes the reasons of the discrepancies.
Exception path(s)	N/A
Post-condition	NILM identification ability is evaluated, allowing assessment of model effectiveness under different day types and assets.
Datasets required	Smart meter (P, Q) and submetering (P) pilot data with 1 min granularity from 1 month to make some training of the NILM algorithms (DS.GR.01)

Output data	• Smart meter data (P, Q) with 15 min granularity. • Submetering data curves (P) with the same granularity as above.
Related KPIs	KPI.NILM.01
Related pilot	Greek pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

GR pilot TC1.3.4

Test case ID	TC1.3.4
Name	State estimation accuracy (GR pilot)
Timeframe	M33-M42
Targets	The target is to enhance DSO grid observability from primary substations all the way to the service transformer level, covering the entire MV network.
Actors involved	• **HEDNO**: Grid operator, providing historical and real-time data • **ICCS**: Technology provider, providing the software performing distribution system state estimation (DSSE)
Assets & systems involved	• Software: DSSE tool • Hardware: ICCS server hosting the software • Measurement systems: SCADA (primary substation), AMI/AMR system (customer premises or MV/LV transformers), PMU (MV/LV transformers)
Triggering event	The DSSE tool runs continuously as a monitoring function
Pre-condition	• Historical data: primary substation measurements (SCADA), load consumption (AMI/AMR), DER generation (AMI/AMR). • Operating topology of the grid (MV). • Access to (near) real-time measurement data gathered from the field: synchronized (voltage/current phasors recorded by PMUs) and conventional (voltage magnitude, power injections delivered by AMI) measurements. • Offline learning stage: The deep neural network (DNN) used for DSSE is trained based on the available historical data, including topology information. Temporal profiles of nodal loads and generation are extracted from this historical data to reflect realistic grid behaviour. To construct a robust and comprehensive training dataset, a probabilistic approach based on Monte Carlo trials is applied to these profiles. The DNN is designed to utilize PMU measurements. To this end, an optimal (i.e., minimum) PMU placement configuration for maximizing DSSE accuracy (i.e., fulfilling a desired MAPE threshold) is also designed at this stage.
Test case description	During the real-time operation stage, the process runs continuously comprising two main subprocesses: 1. The data acquisition subprocess collects the most recent set of PMU data from the phasor data concentrator (PDC). Additionally, the operating grid topology is obtained from the TI process (precedes DSSE process). 2. The state estimation subprocess processes the PMU data to: a) estimate the complex voltages (magnitude and phase angle) of all MV grid nodes b) calculate the power flows through all MV lines based on the aforementioned estimated voltages. Also, periodically, the output of the DSSE process will be cross-validated against conventional field measurements (e.g., load consumption from AMI devices at selected MV/LV transformers). This comparison serves as an additional verification step to confirm grid operating conditions and to identify any potential data inconsistencies.
Exception path(s)	In the event of missing PMU data (e.g., due to communication failure or GPS signal loss), an error message will be sent to the end user, and an event log will be recorded.
Post-condition	The estimated grid state is stored and visualized through the DSSE user interface (UI), which represents the grid using a node-branch (graph-based) model. Operational issues, such as voltage violations

	or line congestions, are highlighted using appropriate color coding for easy identification.
Datasets required	• For the offline learning stage: o Primary substation data: active/reactive power flows (P_{fl}/Q_{fl}) at feeder head, voltage and current magnitude (V, I) at slack bus. o DER data: active/reactive power injection (P_i/Q_i) at DER sites (MV level). o Load data: active/reactive power injection (P_i/Q_i) at service transformers hosting MV consumers or LV consumers (aggregated data). o Topology data: the corresponding grid topologies associated with each historical data snapshot, capturing the system operating configuration. • For real-time operation: o PMU measurements: voltage/current magnitudes and phase angles (V, Va, I, Ia) at selected MV/LV transformers. o AMI measurements: voltage magnitude (V) and power injections (Pi/Qi) at selected MV/LV transformers. o The operating grid topology provided by the TI tool.
Output data	• Estimated nodal voltages for the period under study • Calculated power flows for the period under study • Optimal grid locations for PMU installation • Event logs • Identification of operational issues
Related KPIs	KPI.GR.01
Related pilot	Greek pilot

Results of the experiment
(reported in D6.2)

Qualitative analysis of the results
(reported in D6.2)

GR pilot TC1.4.2

Test case ID	TC1.4.2
Name	RTTR tool for MV line capacity calculation (GR pilot)
Timeframe	M33-M42
Targets	The RTTR tool provides distribution system operators with a low-cost solution to dynamically assess line capacity. The tool exploits existing measurements from the distribution network to estimate the electrical current in individual feeder sections and applies machine learning models to produce **probabilistic short-term forecasts** of current evolution. These forecasts are coupled with **high-resolution weather predictions** (ambient temperature, wind speed, wind direction, and solar radiation), enabling accurate calculation of conductor ampacity and thermal rating in compliance with IEEE standards.
Actors involved	• **HEDNO**: DSO, user of the RTTR tool • **ICCS**: Developer of the RTTR tool
Assets & systems involved	• Software: RTTR tool. • Hardware: ICCS server hosting the software, ICCS DB server hosting the required datasets. • Measurement systems: overhead power-line monitoring device (Sentrisense Line guard) • Cloud: Sentrisense API, IoT MQTT brocker
Triggering event	The RTTR tool runs continuously in the background, collecting measurements from Sentrisense Line Guard devices and weather services. When the user uploads the distribution network topology files, they can trigger a calculation session via the RTTR tool's GUI. This event initiates real-time ampacity and conductor temperature calculations, along with short-term (up to 6 hours) forecasts, which are then presented to the user in the UI.
Pre-condition	• The RTTR tool is installed and operational on the ICCS server with access to the required datasets. • Network topology files (line and feeder data) have been prepared and uploaded to the tool. • Historical current data is available for training the machine learning model. • High-resolution weather forecasts (temperature, wind speed/direction, solar radiation) are available and accessible to the tool. • Communication links between measurement devices, databases, and the RTTR tool are active and reliable.

Test case description	**Setup steps:**
	• The DSO user has collected all required static data for tool input.
	• The DSO and developer of RTTR have established real-time data interface between the equipment and the software.
	• The DSO user accesses the GUI of the RTTR tool and uploads all the necessary data.
	Execution steps:
	• In the **"Topology" tab**, the user uploads a .csv file, with the topological data of the feeder
	  o CSV data including information of the sections of the feeder that are underground or overhead, the cross section and the material of overhead conductor, the section length, the resistance and reactance in (ohm/km), the maximum current and the latitude and longitude of the feeder section end points.
	  o The user selects the asset that these data belong from a drop

	down menu in the GUI
	• In the **"Historical Data" tab**
	  o The user uploads the csv file with the historical data: Either drag and drop the relevant file or using the 'Browse files' button to select the file
	  o The user checks that an overview of the uploaded data is presented as a table, including the columns: timestamp, element, measure, value and unit and that a validation message is presented
	  o The user could select to re-train the machine learning models
	Post-execution steps:
	• In the **"Real-Time Dashboard" section**:
	  o The user validates that the graphs for the conductor's loading and temperature, for the next 6 hours (probabilistic RTTR, static), are presented If not enough failures have occurred, i.e. less than 1% of the total population, in a specific brand/model then the message "Limited Failure Numbers recorded" is printed in the interface
	• In the **"Historical Data Dashboard" section**:
	  o The user can select a time period and get all the forecasts, measurements and actual temperature of the conductor, as well as the associated rating. Download option is available for offline analysis and KPIs calculation

Exception path(s)	Improper files format or data structures in the input files are detected and error messages are presented to the user highlighting the erroneous sections.
Post-condition	The RTTR tool successfully uses existing measurements of the distribution network to estimate the values of the conductor temperature on different feeder sections, while also estimating the future ampacity of the lines, via machine learning. Additionally, the GUI presents to the DSO user graphs for the conductor's loading and temperature and actual thermal rating, for the next 6 hours.
Datasets required	Topological data of the lines: • Section type (underground / overhead) • Conductor cross-sectional area and material • Section length • Electrical parameters (resistance and reactance in Ω/km) • Maximum allowable current • Geographic coordinates (latitude/longitude) of line section endpoints Historical dataset: • Historical current measurements per line section • Associated metadata: timestamp, element, measure, value, unit Real-time measurement dataset: • Live current measurements from the SCADA system regarding the lines. Environmental forecasts: • High-resolution weather forecasts including ambient temperature, wind speed, wind direction, and solar radiation
Output data	• The user goes to historical data tab and downloads historical forecasts and temperature measurements, as well as calculated ratings for the conductor for offline analysis of KPIs. • Data provided via Sentrisense API regarding the actual temperature of the conductors. Used for the validation of the tool
Related KPIs	• KPI.RTTR.01 • KPI.RTTR.02
Related pilot	Greek pilot

Results of the experiment
(reported in D6.2)
Qualitative analysis of the results
(reported in D6.2)

GR pilot TC1.5.3

Test case ID	TC1.5.3
Name	Short-term asset management for UHV/HV transformers (GR pilot)
Timeframe	M33-M42
Targets	This test case will utilize the short-term module of the advanced asset management tool in order to provide information on the condition of transformers, performing Dissolved Gas Analysis, Top Oil Temperature Anomaly detection & prediction, bushings insulation assessment. The designed short term asset management module will perform the following tasks: a) raise alarms, if needed, for specific transformer' components (according to the available measurements) b) present historical records of alarms c) predict possible critical conditions in the future and link them to a failure probability.
Actors involved	• **IPTO**: TSO, user of the asset management tool • **ICCS**: Developer of the asset management tool
Assets & systems involved	• Transformers and transformer on-line monitoring systems • Asset management tool • Server hosting the asset management tool and database
Triggering event	The TSO user logs in to the tool. The user can select to upload further historical data via the respective section and retrain the models. The user can see historical records of alarms in historical data section and see the latest alarm status and future oil predictions in the real time section.
Pre-condition	• An interface to the SFTP server has been established to upload automatically the OLMS data daily. The OLMS data includes at least current measurement, top oil temperature and ambient temperature. • Any further historical data to be provided in the UI is collected in the proper format in a csv file. • Predictive models have been trained, using machine learning, considering the available historical data. • The GUI for the short-term module of the asset management tool has been developed

Test case description	**Setup steps:**
	• The TSO has collected all required data for input to the tool
	Execution steps:
	• The user (TSO) successfully logs into the Grid Management Software and selects the "Asset Management > Short Term" tab
	• In the **"Historical Data Import" tab**:
	  o The user selects one of the registered assets
	  o The user uploads a CSV file containing the historical OLMS data, either by dragging and dropping a file, or browsing to select a file from their system
	Post-execution steps:
	• In the **"Historical Data Import" tab**:
	  o Verify that the file has been uploaded correctly
	• In the **"Real Time Monitoring" tab**:
	  o In '*Bushings*':
	    • the user reports the status of the system (OK or not OK, as well as the colour of the relevant light – green/red)
	    • the user reports the status of each bushing component (Cap H1, Cap H2, Cap Y1), etc., by viewing the relevant table
	  o In '*Dissolved Gas Analysis – DGA*':
	    • the user reports the status of the system ('OK and not

	action suggested' or not OK, as well as the colour of the relevant light – green/red) • the user, by viewing the relevant table, reports the latest data (mean values of last 24 hours measurements), and the overall score, on different gases o In '*Oil Anomaly Detection*': • the user reports whether anomalies have been detected or not, as well as the colour of the relevant light – green/red) • the user, by viewing the relevant figure, reports if the model's output remains within an acceptable range, as defined by horizontal boundaries on the graph o In '*Top Oil Prediction*': • The probability of failure and the 50 and 90 quantiles of top oil temperature forecast for the next six hours are shown • In the **"Historical Analysis" tab**: o The user selects the desired time period and gets DGA scores, bushing alarms, and top oil temperature anomalies logs o The user can download the historical logs for offline assessment
Exception path(s)	Improper files format or data structures in the input files are detected and error messages are presented to the user highlighting the erroneous sections
Post-condition	• In the **"Historical Data Import" tab**: o The preview of the data displayed in table format indicates that the file has been uploaded correctly • In the **"Real Time Monitoring" tab**: o In '*Bushings*': • A system status is indicated (OK/Not OK), with the colour of the relevant light (green/red) • The status of each bushing component (Cap H1, Cap H2, Cap Y1, etc.), is displayed in the relevant table o In '*Dissolved Gas Analysis – DGA*': • A system status is indicated ('OK and not action suggested' or 'not OK'), as well as the colour of the relevant light (green/red) • Data (mean values of last 24 hours measurements), and the overall score, of different gases is displayed in the table o In '*Oil Anomaly Detection*': • It is displayed whether anomalies have been detected or not, as well as the colour of the relevant light – green/red • A figure is presented indicating whether the model's output remains within an acceptable range, as defined by horizontal boundaries on the graph o In *Top Oil Prediction'*: • The failure probability for the next 6 hours is displayed in the relevant table as well as a 50 and 90 quantile of top oil temperature forecast for the next six hours in a graph. • In the **"Historical Analysis" tab**: o The user sees the alarms and DGA scores for the selected period. o The user downloads the alarm logs in CSV format
Datasets required	Transformer historical monitoring data Transformer monitoring data from OLMS
Output data	Core operating measurements: • Top-oil temperature • Ambient temperature • HV current Bushing condition:

	• Capacitance: HV1/HV2/HV3 and LV1/LV2/LV3 • Tan-δ (dissipation factor): HV1/HV2/HV3 and LV1/LV2/LV3 Dissolved Gas Analysis (DGA): • H_2, CH_4, C_2H_2, C_2H_6, C_2H_4
Related KPIs	KPI.AAM.01
Related pilot	Greek pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

GR pilot TC1.6.3

Test case ID	**TC1.6.3**
Name	Topology identification capability (GR pilot)
Timeframe	M33-M42
Targets	The target is to determine the operating grid topology (node-branch configuration) by identifying the status of all switching devices.
Actors involved	• **HEDNO**: Grid operator, providing historical and real-time data • **ICCS**: Technology provider, providing the software performing topological identification (TI)
Assets & systems involved	• Software: TI tool • Hardware: ICCS server hosting the software • Measurement systems: SCADA (primary substation), AMI/AMR system (customer premises or MV/LV transformers), PMU (MV/LV transformers)
Triggering event	The TI tool runs continuously as a monitoring function.
Pre-condition	• Historical data: primary substation measurements (SCADA), load consumption (AMI/AMR), DER generation (AMI/AMR). • Access to (near) real-time measurement data gathered from the field: synchronized (voltage/current phasors recorded by PMUs) and conventional (voltage magnitude, power injections delivered by AMI) measurements. • Offline learning stage: The deep neural network (DNN) used for TI is trained based on the available historical data, including topology information. Temporal profiles of nodal loads and generation are extracted from this historical data to reflect realistic grid behaviour. To construct a robust and comprehensive training dataset, a probabilistic approach based on Monte Carlo trials is applied to these profiles. The DNN is designed to utilize PMU measurements. To this end, an optimal (i.e., minimum) PMU placement configuration for maximizing DSSE accuracy (i.e., fulfilling a desired MAPE threshold) is also designed at this stage.
Test case description	During the real-time operation stage, the process runs continuously comprising two main subprocesses: 1) The data acquisition subprocess collects the most recent set of PMU data from the phasor data concentrator (PDC) 2) The topology identification subprocess processes the PMU data to: a. estimate the status of all switching devices of the grid, b. identify the current node-branch configuration (graph-based model) of the grid, c. provide the estimated topology as an input to the DSSE process for estimating the nodal complex voltages. Also, periodically, the output of the TI process will be cross-validated against conventional field measurements (e.g., load consumption from AMI devices at selected MV/LV transformers). This comparison serves as an additional verification step to confirm the connection status of network components.
Exception path(s)	In the event of missing PMU data (e.g., due to communication failure or GPS signal loss), an error message will be sent to the end user, and an event log will be recorded.
Post-condition	The estimated grid topology is stored and visualized through the TI UI using a node-branch (graph-based) model representation. Topology changes, e.g., reconfiguration by DSO or DER disconnection, are highlighted.

Datasets required	• For the offline learning stage:
	  o Primary substation data: active/reactive power flows (Pfl/Qfl) at feeder head, voltage and current magnitude (V, I) at slack bus
	  o DER data: active/reactive power injection (Pi/Qi) at DER sites (MV level)
	  o Load data: active/reactive power injection (Pi/Qi) at service transformers hosting MV consumers or LV consumers (aggregated data)
	  o Topology data: the corresponding grid topologies associated with each historical data snapshot, capturing the system operating configuration
	• For real-time operation:
	  o PMU measurements: voltage/current magnitudes and phase angles (V, Va, I, Ia) at selected MV/LV transformers
	  o AMI measurements: voltage magnitude (V) and power injections (Pi/Qi) at selected MV/LV transformers

Output data	• Estimated grid topology for the period under study • Identification of topology changes (with respect to previous operating configuration) • Optimal grid locations for PMU installation • Event logs
Related KPIs	KPI.GR.02
Related pilot	Greek pilot

Results of the experiment
(reported in D6.2)

Qualitative analysis of the results
(reported in D6.2)

GR pilot TC1.7.2

Test case ID	TC1.7.2
Name	Network planning tool for investment deferral (GR pilot)
Timeframe	M33-M42
Targets	This test case will utilize the network planning algorithm in order 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.
Actors involved	• **HEDNO**: Grid operator, user of the network planning tool • **ICCS**: Developer of the planning tool
Assets & systems involved	Network planning tool
Triggering event	The DSO utilizes the network planning tool, selecting the option for "investment deferral"
Pre-condition	• The algorithm for investment deferral has been in the network planning tool • The GUI for the network planning tool has been developed • All required input data has been collected: o topology data of the feeder under test, o demand data for a year with hourly resolution per secondary substation, o the power factor per secondary substation, o information on the lines that will be considered for possible upgrade
Test case description	**Setup steps:** • The user (DSO) has collected required data for input to the tool (system topology and load curves per secondary substation) • The user successfully logs in the planning tool **Execution steps:** • In the **"Power Flow" Section**: o In the Topology field the user provides the JSON file containing the topology data of the feeder under test. If loops are in the distribution network the user is asked to select which line is de-energized o In the power curves field, the user provides the CSV file that contains the demand data for a year with hourly resolution per secondary substation o In the cosφ field, the user provides the CSV file that contains the power factor per secondary substation o The user selects the horizon in years to run the analysis of power flow (and a multi-year optimization) and the load growth rate to be considered o In the "Select PV locations" field, the user selects the location of future PV installations, the year that they will be installed and the nominal power in kW o The user clicks on the "Calculate" tab to proceed with the power flow analysis. The user should then click on 'Optimization' • In the **"Optimization" section**: o In the "line types" field, the user uploads a CSV file with the lines that will be considered for possible upgrades o In the "Optimization Goals" field, the user selects 'Investment Deferral' as the optimization goal o In the "Economic Parameters", the user sets the costs to be

	considered by the optimization formulation o In the "Flexibility Parameters", the user defines the maximum flexibility by RES, the RES Power Factor Limit and the Maximum demand flexibility o in 'Battery Energy Storage System Parameters', the user selects the buses (if any) to consider storage options, and the storage system associated parameters o Then, the user clicks on the 'Calculate' button
Exception path(s)	Improper files format or data structures in the input files are detected and error messages are presented to the user highlighting the erroneous sections.
Post-condition	In the **"Optimization Results"**: • Record the year indicated for the proposed investments
Datasets required	• topology data of the feeder under test • secondary substation yearly demand data with hourly resolution • secondary substation power factor • information on the lines considered for possible upgrade
Output data	• For the scenario under study, record the year indicated for the proposed investments • Rerun the case without considering any flexibility (adjusting the proper settings) to calculate the year that the investment would normally occur. • Compare the year of investments to calculate how many years the investments are delayed
Related KPIs	• KPI.GPO.01 • KPI.GPO.02 • KPI.GPO.03
Related pilot	Greek pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

GR pilot TC1.8.1.1

Test case ID	TC1.8.1.1
Name	Baseline consumption forecast (GR pilot)
Timeframe	M33-M42
Targets	Forecast the baseline consumption for a particular consumer
Actors involved	• **HYP**: BFMS responsible partner and asset operator at the Greek pilot • **QUE**: Data Space operator
Assets & systems involved	• Assets at pilot sites, including EMS (SMART BOX) • BFMS • Data Space (Data Space connector deployed at each participant site)
Triggering event	BFMS is automatically set to create a baseline consumption forecast on a periodical basis, for instance a day-ahead forecast
Pre-condition	• Communication of assets with EMS is established (SMART BOX for the Greek pilot) • Communication of EMS with BFMS is established (over the Data Space) • Sufficient and good quality data is received from the BFMS, including power consumption time series and where available user-defined constraints. • BFMS baseline calculation algorithm is available for the target asset types
Test case description	1. Data Acquisition: Consumption data per asset and user preferences (optionally) are retrieved from HEMS/BEMS. 2. Data Pre-processing: Retrieved data undergoes preprocessing for outlier detection and removal. 3. Baseline Forecasting: The Flexibility Forecasting Module generates day-ahead baseline consumption values per asset using historical profiles and machine learning models. 4. Baseline Storage: Forecasted baseline values are stored in the Profiling Storage & Retrieval Service for future use
Exception path(s)	In case of insufficient data due to communication failure or data gaps (e.g., missing, or incomplete consumption data), BFMS could use historical averages.
Post-condition	A baseline forecast consumption profile is created pet asset and stored in the Profiling Storage and Retrieval Service. The baseline forecast is available through the Data Space for market bidding at the NODES platform.
Datasets required	Asset power consumption data from pilots
Output data	Baseline consumption forecast
Related KPIs	• KPI.HEMS.01 • KPI.HEMS.03
Related pilot	Greek pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

GR pilot TC1.8.2.1

Test case ID	TC1.8.2.1
Name	Flexibility consumption forecast (GR pilot)
Timeframe	M33-M42
Targets	Forecast the flexibility consumption for a particular consumer
Actors involved	• **HYP**: BFMS responsible partner and asset operator at the Greek pilot • **QUE**: Data Space operator
Assets & systems involved	• Assets at pilot sites, including EMS • BFMS • Data Space (Data Space connector deployed at each participant site)
Triggering event	BFMS is automatically set to create a baseline consumption forecast on a periodical basis, for instance a day-ahead forecast
Pre-condition	• BFMS flexibility calculation algorithm is available • A baseline consumption forecast has been created and stored in the Profiling Storage & Retrieval Service • Day ahead energy price timeseries available (optionally) • User-defined constraints have been retrieved (optionally)
Test case description	1. Baseline retrieval: BFMS retrieves the previously generated day-ahead baseline consumption forecast for each asset. 2. Market data retrieval: BFMS retrieves day ahead energy price timeseries if available. 3. Flexibility forecast: BFMS generates forecasted flexibility consumption values. 4. Flexibility Storage: Forecasted flexibility values are stored in the Profiling Storage & Retrieval Service for future use
Exception path(s)	In case of unavailable baseline forecast, flexibility values cannot be generated. In case of missing market data, only user-defined constraints will be used.
Post-condition	A flexibility forecast consumption profile is created pet asset and stored in the Profiling Storage and Retrieval Service. The flexibility forecast is available through the Data Space for market bidding at the NODES platform.
Datasets required	Forecasted baseline energy consumption values for each asset
Output data	Flexibility consumption forecast
Related KPIs	• KPI.HEMS.03 • KPI.HEMS.04 • KPI.HEMS.05
Related pilot	Greek pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

GR pilot TC1.8.3.1

Test case ID	TC1.8.3.1
Name	Dispatch of control signals to assets (GR pilot)
Timeframe	M33-M42
Targets	Dispatch control signals to the assets
Actors involved	• **HYP**: BFMS responsible partner and asset operator at the Greek pilot • **NODES**: NODES platform operator • **QUE**: Data Space operator
Assets & systems involved	• Assets at pilot sites, including EMS • BFMS • Data Space (Data Space connector deployed at each participant site) • NODES platform
Triggering event	Flexibility order is matched on the NODES platform
Pre-condition	• BFMS has generated forecasted baseline and flexibility consumption values per asset • DSO/TSO has submitted a bid on the NODES platform • Communication between BFMS, NODES platform and controllable assets is operational
Test case description	1. BFMS retrieves the forecasted baseline and flexibility values for each asset. 2. BFMS communicates forecasted baseline and flexibility consumption values to the NODES platform. 3. The NODES platform matches the flexibility order based on submitted bids. 4. BFMS receives order acceptance from the NODEs platform. 5. BFMS generates appropriate control sequences for each controllable asset based on the matched order. 6. BFMS dispatches control signal to each controllable asset over the Data Space
Exception path(s)	In case there is a communication failure between BFMS and the NODES platform, control action will not be delivered. In case user interferes with the controllable asset, user preference overrides any control action.
Post-condition	Controllable assets receive control signals
Datasets required	Forecasted baseline and flexibility consumption values
Output data	Dispatched control signals to assets
Related KPIs	• KPI.HEMS.02 • KPI.HEMS.04 • KPI.HEMS.05 • KPI.HEMS.06
Related pilot	Greek pilot

Results of the experiment
(reported in D6.2)

Qualitative analysis of the results
(reported in D6.2)

GR pilot TC1.9.1

Test case ID	TC1.9.1
Name	Registration of consumers' preferences (GR pilot)
Timeframe	M33-M42
Targets	To retrieve and save the preferences of the consumers per asset
Actors involved	• **HYP**: BFMS responsible partner and asset operator at the Greek pilot • **QUE**: Data space operator
Assets & systems involved	• Assets at pilot sites, including EMS • BFMS • Data space
Triggering event	Consumer logs in to DR initialization service UI
Pre-condition	• Communication of assets with EMS is established • Communication of EMS with BFMS is established
Test case description	1. Consumer enters the DR initialization service UI 2. Consumer retrieves correct list of assets 3. Consumer enters preferences per asset 4. Preferences are communicated to the BFMS 5. BFMS saves preferences per user and per asset
Exception path(s)	N/A
Post-condition	BFMS incorporates consumer's preferences to its algorithms
Datasets required	List of assets per consumer
Output data	Preferences of consumers per asset
Related KPIs	KPI.HEMS.07
Related pilot	Greek pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

GR pilot TC1.10.1

Test case ID	TC1.10.1
Name	Flexibility procurement in an integrated market (GR pilot)
Timeframe	M34-M42
Targets	Examine a secure, transparent, and scalable TSO–DSO coordination process within a unified flexibility market addressing the requirements of simultaneous flexibility activation across grid levels such as effective coordination, communication and conflict resolution mechanisms
Actors involved	• **HEDNO**: DSO • **IPTO**: TSO • **HYP**: FSP • **ICCS**: FSP • **NODES**: NODES platform operator
Assets & systems involved	Residential assets and virtual batteries and solar plants
Triggering event	HEDNO (DSO): Local/regional grid congestion IPTO (TSO): Requirement for grid balancing
Pre-condition	**DSO and TSO:** • Integration with NODES platform, onboarding and familiarisation • Replication of the grid infrastructure in the test location (done once); insertion of grid node thresholds to communicate capacity limits (can be done multiple times) **FSPs:** • Integration with NODES platform, onboarding and familiarisation • Asset registration and prequalification • Agreement on market design with simultaneous coordination • Definition of a timeline for flexibility trading and activations including coordination **All:** • Data availability and quality considered suitable • Development of coordination tools and mechanisms

Test case description	**Setup steps**
	• Grid state evaluations and operations on behalf of HEDNO and IPTO (NODES platform is ready for trading any time the system operators are in need)
	Execution steps
	• HEDNO and IPTO identify a critical event in their grids
	• Market-based flexibility procurement starts according to the timeline
	• Round 1:
	  o The DSO and TSO submit buy orders
	  o FSPs submit Sell offers
	  o TSO-DSO coordination based on available orders
	  o Integration with the ID market (TSO)
	  o During this round, orders will only be gathered, no matching
	• Round 2
	  o The DSO and TSO submit buy orders
	  o FSPs submit Sell offers
	  o TSO-DSO coordination based on available orders
	  o Manually-triggered auction
	  o Notifications are sent to FSPs
	  o Integration with the ISP1 (TSO)
	• Round 3
	  o The DSO and TSO submit buy orders
	  o FSPs submit Sell offers

	o TSO-DSO coordination based on available orders o Automatic auction o Notifications are sent to FSPs o Integration with the ISP2 (TSO) • Round 4 - Intraday o FSPs, DSO and TSO can submit offers continuously according to need/possibility o Coordination will be performed continuously o Necessary integration with ISP 3 • Coordination scenarios: o Throughout the testing different coordination scenarios will be examined for suitability, grid management and time efficiency o NODES being the sole Market Coordinator based on Rulebook o Hybrid coordination among HEDNO, IPTO and NODES o Multi-level coordination with prioritization acc. To criticality **Post-execution steps** o Evaluation of the flexibility procurement timeline, possible adaptions and the coordination scenarios. o NODES platform tools for coordination will be evaluated for optimization
Exception path(s)	N/A
Post-condition	Evaluation of market set-up, possible adaptions/improvements and conclusion of TSO-DSO coordination scenarios and suitability for flexibility trading in Greece
Datasets required	Simplified grid infrastructure for testing, Asset data (type of asset, location, installed capacity), Baselines, Metering data
Output data	Flexibility activation logs, market prices and volumes
Related KPIs	• KPI.HEMS.02 • KPI.HEMS.03 • KPI.FM.01 • KPI.FM.02 • KPI.FM.04 • KPI.FM.05
Tested in which pilot	Greek pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

GR pilot TC2.1.1

Test case ID	TC2.1.1
Name	Network planning tool for optimal upgrades under budget constraints
Timeframe	M33-M42
Targets	Identify the best upgrades in the system that maximize the RES capacity. The DSO will set in the UI the necessary settings, like budget constraints and flexibility constraints and perform planning with goal to maximize RES penetration. The DSO will view the list of upgrades via the UI of the network planning tool and their associated costs. The maximum RES capacity, according to the current limits in the lines and voltages in the buses, is also presented to the DSO, via the GUI of the tool
Actors involved	• **HEDNO**: Grid operator, user of the network planning tool • **ICCS**: Developer of the planning tool
Assets & systems involved	• Software: Network Planning Tool • Hardware: ICCS server hosting the software • System topology (JSON format) • Historical data of substation loading • Types of lines considered for upgrade
Triggering event	After uploading all the necessary files required and selected the desired settings, the DSO utilizes the network planning tool by selecting the option for "Maximize RES capacity Optimization"
Pre-condition	• The optimisation problem for maximising the RES capacity has been formatted and integrated in the network planning tool • The UI for the network planning tool has been developed • All required input data has been collected: o topology data of the feeder under test, o latitude and longitude of the area, o demand data for a year with hourly resolution per secondary substation, o the power factor per secondary substation, o information on the lines that will be considered for possible upgrade
Test case description	**Setup steps:** • The user (DSO) has collected required data for input to the tool (system topology and load curves per secondary substation) • The user successfully logs in the planning tool **Execution steps:** • In the **"Power Flow" Section**: o In the Topology field the user provides the JSON file containing the topology data of the feeder under test. If loops are in the distribution network the user is asked to select which line is de-energized o In the power curves field, the user provides the CSV file that contains the demand data for a year with hourly resolution per secondary substation o In the cosφ field, the user provides the CSV file that contains the power factor per secondary substation o The user selects the horizon in years to run the analysis of power flow (and a multi-year optimization) and the load growth rate to be considered o In the "Select PV locations" field, the user selects the location of future PV installations, the year that they will be installed and the nominal power in kW o The user clicks on the "Calculate" tab to proceed with the power flow analysis. The user should then click on

	'Optimization'
	• In the **"Optimization" section**:
	  ○ In the "line types" field, the user uploads a CSV file with the lines that will be considered for possible upgrades
	  ○ In the "Optimization Goals" field, the user selects 'Investment Deferral' as the optimization goal
	  ○ In the "Economic Parameters", the user sets the costs to be considered by the optimization formulation
	  ○ In the "Flexibility Parameters", the user defines the maximum flexibility by RES, the RES Power Factor Limit and the Maximum demand flexibility
	  ○ Then, the user clicks on the 'Calculate' button
	Post-execution steps:
	• In the **"Optimization Results"**:
	  ○ A list of the optimal upgrades is presented and their associated costs
	  ○ The maximum RES capacity according to the current limits in the lines and voltages is also presented with the hosting capacity presented per secondary substation

Exception path(s)	Improper files format or data structures in the input files are detected and error messages are presented to the user highlighting the erroneous sections.
Post-condition	The network planning tool allows an increment in the RES penetration in the examined network. Additionally, the tool successfully outputs the required upgrades in the grid in order to achieve the relevant increment in RES penetration.
Datasets required	• topology data of the feeder under test in JSON format • latitude and longitude of the region • demand data for a year with hourly resolution per secondary substation • the power factor per secondary substation • information on the lines that will be considered for possible upgrade
Output data	• A list of the optimal upgrades is presented and their associated costs. • The maximum RES capacity according to the current limits in the lines and voltages is also presented with the hosting capacity presented per secondary substation.
Related KPIs	KPI.GPO.04
Related pilot	Greek pilot

Results of the experiment
(reported in D6.2)
Qualitative analysis of the results
(reported in D6.2)

10.1.2 Swiss pilot site test cases

CH pilot TC1.1.2

Test case ID	TC1.1.2
Name	Voltage variation forecast (CH pilot)
Timeframe	M33-M42, to be updated based on data availability and the area of the test
Targets	To study the voltage variations due to DER fluctuations that might impact the stability of the grid by causing congestion or affecting the protection scheme. This Test Case will analyze the precision of the voltage variation forecast performed in ÉTER and will also check if the voltage variations are within the thresholds defined by the DSO.
Actors involved	• **AEM**: Grid operator providing historical and real-time data • **ETRA**: ÉTER technology provider, with a functionality to analyze the short-term impact of DER in the grid.
Assets & systems involved	• ÉTER tool with a functionality to analyze the short-term impact of DER in the grid • AEM grid meters (P, Q, V, I) • AEM Advanced Metering Infrastructure (exported and imported power) • Weather forecast provider (Open Weather)
Triggering event	The voltage variation forecast is executed after a successful estate estimation forecast is calculated, so it is running continuously, but only in daylight time
Pre-condition	• GIS and topology (it should be already integrated in ÉTER). • Surplus/energy injection/export curves (historical) • State estimation calculated for an upcoming period.
Test case description	Before the own execution of the test, the DSO and ETRA must agree on an area in which it is well known that injection of distributed energy usually happens and define a moment to analyse (preferably, daylight hours). In due time (24hrs ahead and 1 hour ahead) Then: • Forecast the power that will be fed into the grid per prosumer • With the state estimation results, perform an N-X security analysis considering the forecasted energy injected by the prosumers (that might change). This N-X security analysis will raise steady-state security warnings based on insecure gris situations. • Even If no N-X steady state problems are observed, a dynamic analysis is performed simulating the behaviour of the inverters on a solar irradiation reduction or even an asset disconnection • Steady-estate and dynamic security errors are presented in ETER
Exception path(s)	-
Post-condition	Forecast accuracy is evaluated, allowing assessment of model effectiveness and allowing the DSO to reduce voltage variabilities.
Datasets required	• Surplus/energy injection/export curves (1 year). • Weather conditions in the area analyzed (1 year).
Output data	Voltage data (V) in the studied nodes and lines. Also, P, Q, I could be relevant to extract potential further conclusions.
Related KPIs	KPI.SE.01
Related pilot	Swiss pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	

(reported in D6.2)

CH pilot TC1.2.2

Test case ID	TC1.2.2
Name	NILM identification ability (CH pilot)
Timeframe	1 week in December 2025 1 week in May 2026
Targets	Analyze the ability of the NILM module to identify the different loads of households using just the quasi-real time smart meter data as an input.
Actors involved	• **AEM**: Smart meter data 1 min (imported power) • **ETRA**: NILM developer
Assets & systems involved	• AEM Advanced Metering Infrastructure (AMI) • AEM/Customer manual records (main asset activations) • ETRA NILM module
Triggering event	The ESCO or the retailer aims to provide new features to their clients, offering them the possibility to know their disaggregated consumption per asset without need of submetering.
Pre-condition	• A small batch of households with submetering are available to validate the results of NILM • Assets installed in each household are known
Test case description	The selected timeframe, agreed by AEM and ETRA, is one week in December and one week in May, in order to analyse results covering workdays, weekends, and seasonal weather patterns. Then: • The smart meter sends one-minute data (P and Q) to the NILM. Meanwhile, the customer living in the apartment manually registers the activation of main appliances. • The NILM module will be running and storing the Quasi-RT data coming from the smart meter of the analyzed period. After each period • Send data to ETRA. • Then, it will be possible to compare the disaggregation coming from the NILM and the data from the sensors and calculate the precision, the recall and the F1 score of the results.
Exception path(s)	-
Post-condition	NILM identification ability is evaluated, allowing assessment of model effectiveness under different day types and assets.
Datasets required	Smart meter data (P, Q) with 1 min granularity. Ideally from 1 month to make some training of the NILM algorithms (to be assessed during the test).
Output data	• Smart meter data (P, Q) with 1 min granularity • Manual recording of the main asset activations by the customer living in the apartment
Related KPIs	KPI.NILM.01
Related pilot	Swiss pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

CH pilot TC1.3.2

Test case ID	TC1.3.2
Name	State estimation accuracy (CH pilot)
Timeframe	M33-M42
Targets	The target is to increase DSO grid observability, especially in LV networks
Actors involved	• **AEM**: Grid operator providing historical and real-time data • **ETRA**: ÉTER technology provider, with a functionality to perform state estimation
Assets & systems involved	• ÉTER (which includes the topology of the grid) • Grid meter (P, Q, V, I) • AMI (P; while Q, V and I to be verified) • Weather forecast provider (Open Weather) • Topology model of the grid (ETER and AEM data)
Triggering event	Continuously running
Pre-condition	• Historical load and generator measurements • Topology model of the grid (LV) • Access to (near) real-time measurement data gathered from the field: conventional (voltage magnitude, power flows/ injections delivered by SCADA). • Access to weather data (temperature, sunlight).
Test case description	The estate estimation is continuously running and performing two main subprocesses: 1) The data gathering sub process is responsible for receiving (or retrieving) the available and relevant assets' measurements and store them in the system database. These data are heterogeneous in: a. Nature (type) of the measurements obtained b. Retrieving/receiving mechanism c. Granularity d. Distance from current timestamp. Some measurements are received in near real time (SCADA) measurements), whilst others could arrive delayed up to a month (Smart meters) 2) The estimation sub process will consider all data stored in the system database and will: a. Estimate the P & Q of the loads and generators in the network based on historical measurements, weather conditions, calendar and other exogenous variables. b. Forecast the near future status of the P & Q for the loads and generators in the network c. On (near) real time and near future grid state estimation, calculate the power flows (P, Q, V, I) and identify potential congestion and other security problems Also, periodically: • ETRA will compare the estimated values of P, Q, V, I by the module with the overall set of data available (we performed the test with reduced data) and will calculate the MAE also considering the impact of accuracy of weather data predictions.
Exception path(s)	There could be situations with not enough data to accurately estimate the loads and calculate the power flow. This will be warned to the end user and logged
Post-condition	The measurements estimated of the network elements are obtained and displayed in the topology representation of ÉTER. Also, the security problems are presented
Datasets required	• Power curves (P, Q) of the required smart meters with 15 mins

	granularity in the analysed period. • Voltage and current of some selected smart meters (in certain periods) to assess state estimation accuracy (TBV) • Substation measurements for buses and feeder: P, Q, V & I • Weather data from the analyzed period. • Status of the topology in the analyzed period.
Output data	• P, Q, V, I from the different analysed nodes. • Power losses of the lines in the analyzed period.
Related KPIs	KPI.SE.02
Related pilot	Swiss pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

CH pilot TC1.6.1

Test case ID	TC1.6.1
Name	Topology identification ability (CH pilot)
Timeframe	M33-M42
Targets	Determine both the connections and line impedances of the selected part of the grid
Actors involved	• **AEM**: Grid operator providing historical and real-time data • **ETRA**: ÉTER technology provider, with a functionality to detect topology.
Assets & systems involved	• Grid meter (P, Q, V, I) • AMI system (P; while Q, V and I to be verified) • ÉTER (which includes a topology identification module). • Incomplete topology model of the grid (AEM)
Triggering event	DSO needs to know how the components of the network are interconnected
Pre-condition	• The connections details to the smart meter database. • The identifiers of the smart meters in the network to identify. • The name of the network to create. • The format and location of the analyzed network. Available network parameters must be potential bus-branch configurations (topology), bus (generation/ load, installed capacity etc.) and branch parameters (line impedance, shunt elements etc.).
Test case description	Before the own execution of the test, the DSO and ETRA must agree on an area in which the DSO well known the topology in a certain period (the topology should have changed in that period to assess if the module can detect those changes). Then: • The DSO must send to ETRA the topology data of the selected area and the historical data (P, Q, V, I) coming from SCADA. • ETRA will run power flows with historical data coming from SCADA to perform a voltage correlation analysis. • This voltage correlation analysis will return the topology identified. • ETRA will compare the topology estimated by the module with the one provided initially by the DSO.
Exception path(s)	N/A
Post-condition	After analysing all smart meter data and applying the techniques, the resulting topology will be returned in the format specified in the execution parameters.
Datasets required	• Power curves (P, Q, V, I) of the required smart meters with 15 mins granularity (1 year). • Status of the topology in the analysed period.
Output data	Voltage data (V) from the smart meters in the studied area. Also, P, Q, I could be relevant to extract potential further conclusions.
Related KPIs	KPI.TI.01
Related pilot	Swiss pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

CH pilot TC1.8.1.3

Test case ID	TC1.8.1.3
Name	Baseline consumption forecast (CH pilot)
Timeframe	M33-M42
Targets	To forecast the baseline consumption for a particular consumer
Actors involved	• **HYP**: BFMS responsible partner • **AEM**: Asset operator at the Swiss pilot • **QUE**: Data Space operator
Assets & systems involved	• Assets at pilot sites, including EMS • BFMS • Data Space (Data Space connector deployed at each participant site)
Triggering event	BFMS is automatically set to create a baseline consumption forecast on a periodical basis, for instance a day-ahead forecast.
Pre-condition	• Communication of assets with EMS is established (Flexo for the Swiss pilot) • Communication of EMS with BFMS is established (over the Data Space) • Sufficient and good quality data is received from the BFMS, including power consumption time series and where available user-defined constraints. • BFMS baseline calculation algorithm is available for the target asset types
Test case description	1. Data Acquisition: Consumption data per asset and user preferences (optionally) are retrieved from HEMS/BEMS 2. Data Pre-processing: Retrieved data undergoes preprocessing for outlier detection and removal 3. Baseline Forecasting: The Flexibility Forecasting Module generates day-ahead baseline consumption values per asset using historical profiles and machine learning models 4. Baseline Storage: Forecasted baseline values are stored in the Profiling Storage & Retrieval Service for future use
Exception path(s)	In case of insufficient data due to communication failure or data gaps (e.g., missing, or incomplete consumption data), BFMS could use historical averages
Post-condition	• A baseline forecast consumption profile is created pet asset and stored in the Profiling Storage and Retrieval Service. • The baseline forecast is available through the Data Space for market bidding at the NODES platform.
Datasets required	Asset power consumption data from pilots
Output data	Baseline consumption forecast
Related KPIs	• KPI.HEMS.01 • KPI.HEMS.03
Related pilot	Swiss pilot

Results of the experiment
(reported in D6.2)

Qualitative analysis of the results
(reported in D6.2)

CH pilot TC1.8.2.3

Test case ID	TC1.8.2.3
Name	Flexibility consumption forecast (CH pilot)
Timeframe	M33-M42
Targets	To forecast the flexibility consumption for a particular consumer
Actors involved	• **HYP**: BFMS responsible partner • **AEM**: Asset operator at the Swiss pilot • **QUE**: Data Space operator
Assets & systems involved	• Assets at pilot sites, including EMS • BFMS • Data space (Data Space connector deployed at each participant site)
Triggering event	BFMS is automatically set to create a flexibility consumption forecast on a periodical basis, for instance a day-ahead forecast.
Pre-condition	• BFMS flexibility calculation algorithm is available • A baseline consumption forecast has been created and stored in the Profiling Storage & Retrieval Service • Day ahead energy price timeseries available (optionally) • User-defined constraints have been retrieved (optionally)
Test case description	1. Baseline retrieval: BFMS retrieves the previously generated day-ahead baseline consumption forecast for each asset. 2. Market data retrieval: BFMS retrieves day ahead energy price timeseries if available. 3. Flexibility forecast: BFMS generates forecasted flexibility consumption values. 4. Flexibility Storage: Forecasted flexibility values are stored in the Profiling Storage & Retrieval Service for future use.
Exception path(s)	• In case of unavailable baseline forecast, flexibility values cannot be generated • In case of missing market data, only user-defined constraints will be used
Post-condition	• A flexibility forecast consumption profile is created pet asset and stored in the Profiling Storage and Retrieval Service. • The flexibility forecast is available through the Data Space for market bidding at the NODES platform.
Datasets required	Forecasted baseline energy consumption values for each asset
Output data	Flexibility consumption forecast
Related KPIs	• KPI.HEMS.03 • KPI.HEMS.04 • KPI.HEMS.05
Related pilot	Swiss pilot

Results of the experiment
(reported in D6.2)

Qualitative analysis of the results
(reported in D6.2)

CH pilot TC1.8.3.3

Test case ID	TC1.8.3.3
Name	Dispatch of control signals to assets (CH pilot)
Timeframe	M33-M42
Targets	To dispatch control signal at the assets
Actors involved	• **HYP**: BFMS responsible partner • **AEM**: Asset operator at the Swiss pilot • **NODES**: NODES platform operator • **QUE**: Data Space operator
Assets & systems involved	• BFMS • Data space (Data Space connector deployed at each participant site) • NODES platform • Assets at pilot sites, including EMS
Triggering event	Flexibility order is matched on the NODES platform
Pre-condition	• BFMS has generated forecasted baseline and flexibility consumption values per asset • DSO has submitted a bid on the NODES platform • Communication between BFMS, NODES platform and controllable assets is operational
Test case description	1. BFMS retrieves the forecasted baseline and flexibility values for each asset. 2. BFMS communicates forecasted baseline and flexibility consumption values to the NODES platform. 3. The NODES platform matches the flexibility order based on submitted bids. 4. BFMS receives order acceptance from the NODEs platform. 5. BFMS generates appropriate control sequences for each controllable asset based on the matched order. 6. BFMS dispatches control signal to each controllable asset over the Data Space.
Exception path(s)	• In case there is a communication failure between BFMS and the NODES platform, control action will not be delivered. • In case user interferes with the controllable asset, user preference overrides any control action.
Post-condition	Controllable assets receive control signals
Datasets required	Forecasted baseline and flexibility consumption values
Output data	Dispatched control signals to assets
Related KPIs	• KPI.HEMS.02 • KPI.HEMS.04 • KPI.HEMS.05 • KPI.HEMS.06
Related pilot	Swiss pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

CH pilot TC1.9.2

Test case ID	TC1.9.2
Name	Registration of consumers' preferences (CH pilot)
Timeframe	M33-M42
Targets	To retrieve and save the preferences of the consumers per asset
Actors involved	• HYP – BFMS responsible partner • AEM – Asset operator at the Swiss pilot • QUE – Data Space operator
Assets & systems involved	• Assets at pilot sites, including EMS • BFMS • Data space (Data Space Connector deployed at each participant site)
Triggering event	Consumer logs in to DR initialization service UI
Pre-condition	• Communication of assets with EMS is established • Communication of EMS with BFMS is established • DR initialization service UI is operational and accessible by the consumer
Test case description	1. Consumer accesses the DR initialization service UI. 2. The DR initialization service UI retrieves and displays the list of assets from the EMS over the Data Space. 3. Consumer enters preferences per asset (e.g., comfort settings, operational limits). 4. Provided preferences are communicated from the UI to the BFMS over the Data Space. 5. BFMS saves preferences, associating them with specific user and each asset.
Exception path(s)	In case there is a communication failure between the BFMS and the UI, predefined default values will be applied.
Post-condition	BFMS incorporates consumer's preferences into its flexibility forecasting algorithms. Preferences remain available for future DR events participation.
Datasets required	List of assets alongside their metadata per consumer
Output data	Preferences of consumers per asset
Related KPIs	KPI.HEMS.07
Related pilot	Swiss pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

CH pilot TC1.10.3

Test case ID	TC1.10.3
Name	Peak shaving using local assets (CH pilot)
Timeframe	M33-M42
Targets	Verify the data pipeline, market functionalities and the parameters for the DSO and FSP algorithms to be ready for the first market test in TC5.2.1
Actors involved	• **AEM**: DSO • **SUPSI**: FSP – represents 2 FSPs; 1 representing real assets; 2 representing virtual assets to replicate a more realistic market replication • **NODES**: Platform operator • Indirect involvement as data provider of **HYP** (EMS - Metering data provider/baseline provider)
Assets & systems involved	• Public EV chargers and assets belonging to the local cinema and kindergarten will be controlled to perform real activations in the market, while residential assets (i.e. electric boilers) will be virtually control thanks to the use of a dedicated software provided by SUPSI. • HYP's BFMS is interconnected to SUPSI providing the baselines per asset.
Triggering event	Prepare and test the market operations for the kick-off that will take place during TC5.2.1
Pre-condition	• System operators and FSPs integrate with NODES platform • Onboarding and familiarization • DSO: Replication of the grid infrastructure in the test location • FSPs: Asset registration and prequalification • All: Data availability and quality considered suitable • Bilateral discussions among DSO and NODES to understand the requirements for secure and efficient flexibility procurement
Test case description	1. HYPERTECH forecasts the baseline and available flexibility upon receiving asset and meter data of the controllable assets from AEM within the pilot. 2. The baseline per asset is shared with SUPSI to calculate a respective baseline per portfolio. 3. The baselines per portfolio are uploaded to NODES platform. 4. When AEM has identified the need for flexibility in the grid, the DSO places a buy order on the market platform. 5. SUPSI as the FSP places sell orders on the NODES platform. 6. The submission of buy or sell orders can be performed as a proactive measure to demand or offer flexibility, or as a reply to an existing bid. 7. NODES platform clears the market continuously by applying pay-as-bid. 8. Involved parties, i.e. the respective FSP and DSO get notified when corresponding orders match. 9. FSP communicates the list of assets to be activated and the corresponding setpoints according to the match to the EMS manager (HYP). 10. Control signals are then sent to the pilot leader (AEM) to proceed with the actual activations and service delivery. 11. The FMO validates the correct delivery of flexibility from the FSP to the DSO using metering data of the controllable assets and synthetic data for the asset without applied controlling system.
Exception path(s)	N/A

Post-condition	• Evaluation of mechanisms and results, flexibility asset potential and baselines, identification of challenges and next steps • Evaluation of operational process • Evaluation of data quality and accuracy • Evaluation of baseline methodology per asset (optional) • Evaluation of number of grid limitations solved
Datasets required	• Simplified grid infrastructure for testing • Asset data (type of asset, location, installed capacity) • Baselines • Metering data
Output data	Flexibility activation logs, market prices and volumes, baselines
Related KPIs	• KPI.HEMS.02 • KPI.HEMS.03 • KPI.FM.03 • PI.FM.04
Related pilot	Swiss pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

CH pilot TC5.1.1

Test case ID	TC5.1.1
Name	Flexible asset management for peak reduction at the secondary substation
Timeframe	• Autumn-Winter 1 day (full asset activations) • Autumn-Winter 1 week (limited asset activations) • Winter-Spring 1 week (limited asset activations) • Winter-Spring 1 day (full asset activations)
Targets	• Enable flexibility control for small flexibility assets • Reduce daily peaks at the secondary substation (MV/LV transformer)
Actors involved	• **AEM:** DSO and pilot manager • **HYP**: EMS • **SUPSI**: FSP + FSP virtual, asset tech support • **HPOW**: data tech support
Assets & systems involved	• AEM heat pumps, EV chargers, electric boilers (simulated) • AMI, grid meters, submeters and temperature and humidity sensors, control gateways, AEM's EV charger platform • Forecasters (demand, production, flexibility) • Flexibility market automatically submits bids and offers using AEM/SUPSI scripts. • Pilot data management platform (REST API)
Triggering event	Power peaks at the substation. Daily peaks are morning (6:00 – 9:00) and evening (17:00 – 20:00)
Pre-condition	• Enough flexibility assets available • Flexible assets that are directly controlled must be monitored at asset level with live and real time data. Control gateways must be installed, tested. Integration into the data exchange platform with a dedicated API should be done. • Flexible assets that are not directly controlled must be modelled, and there must be sufficient technical specifications available. • Database with dedicated REST API • Forecasting algorithms for baseline and flexibility
Test case description	1. Forecasts are used to calculate the energy demand at the local secondary substation, where a dedicated grid meter measures the demand at the MV/LV transformer, 24 hours in advance. 2. The available flexibility for the next 24 hours is estimated. 3. The forecasted baseline is used to identify the targeted period in which to perform the control actions, with the aim of reducing the identified peak. 4. The required flexibility is aggregated and coordinated by the FSP, who request the activation of a specific asset portfolio. 5. Activation is monitored during the event by the DSO's metering infrastructure at grid level and by submeter devices at asset level. 6. Data is analyzed and saved for validation and KPI calculation.
Exception path(s)	For the sake of completeness, all flexible assets that are not subject to, or eligible for, direct control will be simulated. This will enable the full potential of the pilot to be analysed.
Post-condition	Reducing peaks is an economically oriented optimisation for AEM as a DSO and its customers. Customers are charged for the highest peak produced in a month (starting from 2.2 kW), while AEM is charged by the cantonal DSO, which manages the HV grid. This scenario creates a win-win situation for both residential and

	commercial property owners and AEM, who can work together to reduce costs. Peak optimisation will become increasingly important soon due to rising energy demand and local production, as it will help to postpone significant grid investment while maintaining service quality.
Datasets required	• Grid meter data: historical and live data in real time • Submeter data for flexible assets: historical and live data in real time • Smart meter data on the PODs: historical data and live data • 24-hour predictions: minimum once a day • Asset specification • Grid topology data • Weather data
Output data	• Flexibility activation logs (power and duration) • Grid and PODs power profiles after activation for validation
Related KPIs	• KPI.CH.02 • KPI.CH.03 • KPI.CH.04 • KPI.CH.06
Related pilot	Swiss pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

CH pilot TC5.2.1

Test case ID	TC5.2.1
Name	Local flexibility market between the local DSO and two FSPs
Timeframe	• Autumn-Winter 1 day (full asset activations) • Autumn-Winter 1 week (limited asset activations) • Winter-Spring 1 week (limited asset activations) • Winter-Spring 1 day (full asset activations)
Targets	The main purpose is to validate the launch of the flexibility market for the Swiss pilot project in its most complete form. The test will consider the interactions between all involved actors (DSOs, FSPs, and other technical partners) and will focus on assessing the potential benefits of aggregating all relevant DERs under a secondary substation (MV/LV transformer).
Actors involved	• **AEM:** DSO and pilot manager • **HYP**: EMS • **SUPSI**: FSP + FSP virtual, asset tech support • **HPOW**: data tech support • **NODES**: FMO
Assets & systems involved	• Assets: heat pumps, EV chargers, electric boilers (simulated) • Advanced Metering Infrastructure (AMI), grid meters, submeters and temperature and humidity sensors, control gateways, AEM's EV charger platform • Forecasters (demand, production, flexibility) • Flex Market automatically submits bids and offers using AEM/SUPSI scripts. • Pilot data management platform (REST API) • NODES flexibility market platform
Triggering event	There are several reasons why one might need to purchase flexibility from a local market. The test described here focuses on the interactions between various market participants to enable the exchange of services. Specifically, the platform will provide flexibility to the local DSO, though possible aggregation with other buyers will be assessed based on the test results. The event is triggered when the DSO requests flexibility on the platform, which is then matched by an FSP's flex offer.
Pre-condition	• All pre-conditions described in UC 5.1 • NODES platform onboarding for buyers and sellers (DSO, FSP) • Deploy of an automatic offer submission script (FSP) • Deploy of an automatic bid submission script (DSO) • Forecasts and validation data integrated in the NODES platform • Bilateral tests on the market platform to verify the data pipeline, activations, parameter tuning
Test case description	1. Predictions of demand and flexibility are used to identify the needs for the DSO and period of potential activations for the FSP. 2. Once the list of assets is identified for each time slot, the FSP is responsible for the aggregation, while the DSO must identify the flexibility needs. 3. Data is then uploaded to the platform**,** and the market is cleared. 4. Winning bids and offers are communicated to the actors 5. The FSP once identified the assets that are eligible to be controlled requests the activations. 6. Measurement and verification procedure are performed on the platform to check the success of the activations.

	7. Results data are analyzed and saved for validation and KPI calculation.
Exception path(s)	For the sake of completeness, all flexible assets that are not subject to, or eligible for, direct control will be simulated. This will enable the full potential of the pilot to be analysed. Ensuring a reliable data pipeline is essential for market operations. Data must be regularly monitored and verified, and AEM must promptly act to restore communication when issues occur.
Post-condition	Market dynamics, scalability potential and flexibility prices are the most relevant aspects that will be analyzed based on test results.
Datasets required	• All datasets introduced in TC5.1.1 and TC5.2.1 • Price scheme • Bid and offer creation tuning parameters (DSO and FSP) • Flexibility asset locations (anonymized asset location)
Output data	• Grid meters, smart meters, submeters (power) • Market logs (bids, offers, prices) • Flexibility activation logs (power and duration)
Related KPIs	• KPI.CH.01 • KPI.CH.05 • KPI.CH.06
Related pilot	Swiss pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

10.1.3 Spanish pilot site test cases

SP pilot TC1.1.1

Test case ID	TC1.1.1
Name	Voltage variation forecast (SP pilot)
Timeframe	M33-M42
Targets	To study the voltage variations due to DER fluctuations that might impact the stability of the grid by causing congestion or affecting the protection scheme. This TC will analyze the precision of the voltage variation forecast performed in ÉTER and will also check if the voltage variations are within the thresholds defined by the DSO.
Actors involved	• **ANELL**: Grid operator, historical and real-time data provider • **AEM**: Grid operator, historical and real-time data provider • **ETRA**: ÉTER technology provider, with a functionality to analyze the short-term impact of DER in the grid.
Assets & systems involved	• ÉTER • SCADA (P, Q, V, I) from the nodes • Weather forecast provider (Open Weather) • Smart meter data (exported and imported power)
Triggering event	The voltage variation forecast is executed after a successful state estimation forecast is calculated, so it is running continuously, but only in daylight time
Pre-condition	• GIS and topology (it should be already integrated in ÉTER) • Surplus/energy injection/export curves (historical) • State estimation calculated for an upcoming period
Test case description	Before the own execution of the test, the DSO and ETRA must agree on an area in which it is well known that injection of distributed energy usually happens and define a moment to analyse (preferably, daylight hours). In due time **(24hrs ahead and 1 hour ahead)**, then: • Forecast the power that will be fed into the grid per prosumer • With the state estimation results, perform an N-X security analysis considering the forecasted energy injected by the prosumers (that might change). This N-X security analysis will raise steady-state security warnings based on insecure grid situations. • Even If no N-X steady state problems are observed, a dynamic analysis is performed simulating the behaviour of the inverters on solar irradiation variations or asset disconnection. Variation of voltages observer are stored in the relevant KPI (KPI.SE.01) for its analysis • Steady-state and dynamic security errors are presented in ETER • On D+1, when real measurements are received, the accuracy of the state estimation will be stored in the relevant KPI (KPI.SE.02) by comparing to these measurements
Exception path(s)	-
Post-condition	Forecast accuracy is evaluated, allowing assessment of model effectiveness and allowing the DSO to reduce voltage variabilities.
Datasets required	• Surplus/energy injection/export curves (1 year). • Weather conditions in the analysed area (1 year), including solar irradiation • Distributed PV generation details at the specific area.
Output data	Voltage data (V) in the studied nodes and lines. Also P,Q,I could be relevant to extract potential further conclusions

Related KPIs	• KPI.SE.01 • KPI.SE.02
Related pilot	Spanish pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

SP pilot TC1.2.1

Test case ID	TC1.2.1
Name	NILM identification ability (SP pilot)
Timeframe	M33-M42
Targets	To analyze the ability of the NILM module to identify the different loads of a household using just the RT smart meter data as an input
Actors involved	• **IMPULSA**: Provides the consumption data from Spanish pilot • **ETRA**: NILM developer
Assets & systems involved	• Smart meter • Consumption sensors • Smart home gateway • NILM module
Triggering event	The ESCO or the retailer aims to provide new features to their clients, offering them the possibility to know their disaggregated consumption per asset without need of submetering.
Pre-condition	• Have a small batch of households to validate NILM results • Know the assets installed in each household
Test case description	Before the own execution of the test, the pilot site and ETRA must agree on the timeframe of the test. It has been agreed in a week in December and a week in May in order to analyse the results covering workdays, weekends and cold and hot weathers. Then: • The smart home gateway must send the data from the smart meter to the NILM module during the defined periods. It should also store the data from the sensors. • The NILM module will be running and storing the RT data coming from the smart home gateway of the analysed period. After each period • The smart home gateway must send the data stored from the sensors to ETRA, • Then, it will be possible to compare the disaggregation coming from the NILM and the data from the sensors and calculate the precision, the recall and the F1 score of the results. • The testing in four different pilot sites will also allow to get insights about whether the different identification ability is similar or different between pilot sites and analyzes the reasons of the discrepancies.
Exception path(s)	N/A
Post-condition	NILM identification ability is evaluated, allowing assessment of model effectiveness under different day types and assets.
Datasets required	Smart meter (P, Q) and submetering (P) pilot data with 1 min granularity from 1 month to make some training of the NILM algorithms (DS.ES.01).
Output data	• Smart meter data (P, Q) with 1 min granularity. • Submetering data curves (P) with the same granularity as above.
Related KPIs	KPI.NILM.01
Related pilot	Spanish pilot

Results of the experiment
(reported in D6.2)
Qualitative analysis of the results
(reported in D6.2)

SP pilot TC1.3.3

Test case ID	TC1.3.3
Name	State estimation calculation (SP pilot)
Timeframe	M33-M42
Targets	The target is to increase DSO grid observability, especially in LV networks
Actors involved	• **ANELL**: Grid operator, historical and real-time data provider • **ETRA**: ÉTER technology provider, with a functionality to identify topology
Assets & systems involved	• ÉTER (which includes the topology of the grid). • SCADA (P, Q, V, I). • AMI system (P, Q, V, I). • Weather forecast provider (Open Weather).
Triggering event	The process is continuously running
Pre-condition	• Historical load and generator measurements • Topology model of the grid (MV & LV) • Access to (near) real-time measurement data gathered from the field: conventional (voltage magnitude, power flows/ injections delivered by SCADA) • Access to weather data (temperature, sunlight)
Test case description	The state estimation is continuously running and performing two main subprocesses: • The data gathering sub process is responsible of receiving (or retrieving) the available and relevant assets' measurements and store them in the system database. These data are heterogeneous in: o Nature (type) of the measurements obtained o Retrieving/receiving mechanism o Granularity o Distance from current timestamp. Some measurements are received in near real time (SCADA) measurements), whilst other could arrive delayed up to a month (Smart meters) • The estimation sub process will consider all data stored in the system database and will: o For all grid energy supply or delivery points with no real time measurements available, estimate the P & Q based on historical measurements, weather conditions, calendar and other exogenous variables. This data is usually known as pseudo-measurements o Estimated pseudo-measurements and real time measurements will be combined and power flow will be calculated. Since pseudo-measurements are not totally accurate, power flow will most likely not converge. o A certain level of confidence is given to each measurement, having the real time SCADA measurements the highest and pseudo-measurements the lowest. o A mathematical process is applied to modify the initial set of measurements so that at the end they are mathematically correct from the point of view of its power flows, and at the same time the changes applied are minimized and proportional to the level of confidence of the measurement. • Security analysis is applied to the estimated power flow (real time and forecasted). and results are stored

Exception path(s)	There could be situations with not enough data to accurately estimate the loads and calculate the power flow. This will be warned to the end user and logged
Post-condition	The measurements estimated of the network elements are obtained and displayed in the topology representation of ÉTER. Also, the security problems are presented
Datasets required	• Power curves (P,Q) of the required smart meters with 60 minutes in the analysed period. • Voltage and current of some selected smart meters (in certain periods) to assess state estimation accuracy • Substation measurements for buses and feeder: P, Q, V & I • Weather data from the analysed period. • Status of the topology in the analysed period. • Test cycles from PLC networks
Output data	Estimated P, Q, V, I from all grid nodes
Related KPIs	KPI.SE.02
Related pilot	Spanish pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

SP pilot TC1.4.1

Test case ID	TC1.4.1
Name	RTTR tool for MV lines capacity calculation (SP pilot)
Timeframe	M33-M42
Targets	The RTTR tool provides distribution system operators with a low-cost solution to dynamically assess line capacity. The tool exploits existing measurements from the distribution network to estimate the electrical current in individual feeder sections and applies machine learning models to produce **probabilistic short-term forecasts** of current evolution. These forecasts are coupled with **high-resolution weather predictions** (ambient temperature, wind speed, wind direction, and solar radiation), enabling accurate calculation of conductor ampacity and thermal rating in compliance with IEEE standards.
Actors involved	• **ANELL**: DSO, user of the RTTR tool • **ICCS**: Developer of the RTTR tool
Assets & systems involved	• Software: RTTR tool. • Hardware: ICCS server hosting the software, ICCS DB server hosting the required datasets. • Measurement systems: overhead power-line monitoring device (Sentrisense Line guard) • Cloud: Sentrisense API, IoT MQTT brocker
Triggering event	The RTTR tool runs continuously in the background, collecting measurements from Sentrisense Line Guard devices and weather services. When the user uploads the distribution network topology files, they can trigger a calculation session via the RTTR tool's GUI. This event initiates real-time ampacity and conductor temperature calculations, along with short-term (up to 6 hours) forecasts, which are then presented to the user in the UI.
Pre-condition	• The RTTR tool is installed and operational on the ICCS server with access to the required datasets. • Network topology files (line and feeder data) have been prepared and uploaded to the tool. • Historical current data is available for training the machine learning model. • High-resolution weather forecasts (temperature, wind speed/direction, solar radiation) are available and accessible to the tool. • Communication links between measurement devices, databases, and the RTTR tool are active and reliable.

Test case description	**Setup steps:**
	• The DSO user has collected all required static data for tool input.
	• The DSO and developer of RTTR have established real-time data interface between the equipment and the software.
	• The DSO user accesses the GUI of the RTTR tool and uploads all the necessary data.
	Execution steps:
	• In the **"Topology" tab**, the user uploads a .csv file, with the topological data of the feeder
	  o CSV data including information of the sections of the feeder that are underground or overhead, the cross section and the material of overhead conductor, the section length, the resistance and reactance in (ohm/km), the maximum current and the latitude and longitude of the feeder section end points.
	  o The user selects the asset that these data belong from a drop

	down menu in the GUI • In the **"Historical Data" tab** o The user uploads the csv file with the historical data: Either drag and drop the relevant file or using the 'Browse files' button to select the file o The user checks that an overview of the uploaded data is presented as a table, including the columns: timestamp, element, measure, value and unit and that a validation message is presented o The user could select to re-train the machine learning models **Post-execution steps:** • In the **"Real-Time Dashboard" section**: o The user validates that the graphs for the conductor's loading and temperature, for the next 6 hours (probabilistic RTTR, static), are presented If not enough failures have occurred, i.e. less than 1% of the total population, in a specific brand/model then the message "Limited Failure Numbers recorded" is printed in the interface • In the **"Historical Data Dashboard" section**: • The user can select a time period and get all the forecasts, measurements and actual temperature of the conductor, as well as the associated rating. Download option is available for offline analysis and KPIs calculation
Exception path(s)	Improper files format or data structures in the input files are detected and error messages are presented to the user highlighting the erroneous sections.
Post-condition	The RTTR tool successfully uses existing measurements of the distribution network to estimate the values of the conductor temperature on different feeder sections, while also estimating the future ampacity of the lines, via machine learning. Additionally, the GUI presents to the DSO user graphs for the conductor's loading and temperature and actual thermal rating, for the next 6 hours.
Datasets required	Topological data of the lines: • Section type (underground / overhead) • Conductor cross-sectional area and material • Section length • Electrical parameters (resistance and reactance in Ω/km) • Maximum allowable current • Geographic coordinates (latitude/longitude) of line section endpoints Historical dataset: • Historical current measurements per line section • Associated metadata: timestamp, element, measure, value, unit Real-time measurement dataset: • Live current measurements from the SCADA system regarding the lines. Environmental forecasts: • High-resolution weather forecasts including ambient temperature, wind speed, wind direction, and solar radiation
Output data	• The user goes to historical data tab and downloads historical forecasts and temperature measurements, as well as calculated ratings for the conductor for offline analysis of KPIs. • Data provided via Sentrisense API regarding the actual temperature of the conductors. Used for the validation of the tool
Related KPIs	• KPI.RTTR.01 • KPI.RTTR.02
Related pilot	Spanish pilot

Results of the experiment
(reported in D6.2)
Qualitative analysis of the results
(reported in D6.2)

SP pilot TC1.5.4

Test case ID	TC1.5.4
Name	Long term asset management for smart metering equipment of DSOs (SP pilot)
Timeframe	M33-M42
Targets	DSO performs end-of-life assessment of smart meters and critical smart meter detection using the long-term module of the advanced asset management tool
Actors involved	• **ANELL**: DSO, user of the asset management tool • **ICCS**: Developer of the asset management tool
Assets & systems involved	• Server hosting the database and the advanced asset management tool • DSO Smart meters data collection system for the extraction of measurements (AMI) • DSO asset management system: for the extraction of smart meter installation and replacement data • Software: asset management tool
Triggering event	After uploading all the necessary files required and selecting the desired settings, the DSO utilizes the asset management tool to view the EoL of smart meters, expected failures per smart meter models, and critical meters in the network.
Pre-condition	• Smart meter historical measurement data are automatically uploaded to the SFTP server • All required information for the smart meters has been collected: o installation/replacement data o MV/LV substations the smart meters are connected to o geodata (latitude, longitude) of secondary substations (optional) • Operational module for the calculation of EoL curves (and predictions of failures based on them) • Developed machine learning model for the identification of critical smart meters • Deployed GUI for the long-term module of the asset management tool
Test case description	**Setup steps:** • The DSO user has collected all required data for input to the tool • Interface and data upload to SFTP server has been tested. **Execution steps:** • The DSO user successfully logs in the Grid Management Software and selects under "Asset Management – Smart Meters" the "EoL Curves & Critical Meters Analysis tab. o In the **"Smart Meters Data Import" section**, the user (DSO) uploads historical data about the smart meters (location, IDs, installation, meter point, etc.) in CSV format[1] o In the **"Critical Smart Meters Analysis" section**, the user uploads a CSV file containing the geodata of the secondary substations to view the calculated critical smart meters on map. **Post-execution steps:** • In the **"End of Life Curves Analysis" section**: o Using the drop-down options the user selects the brand and model of a smart meter ✓ If not enough failures have occurred, i.e. less than 1% of the

[1] This file should include a row per smart meter that includes information about the metering point, the secondary substation that it belongs to, the installation date, the brand and the model, etc.

	total population, in a specific brand/model then the message “Limited Failure Numbers recorded” is printed in the interface ✓ If adequate number of failures have occurred, the user views the EoL curve that is generated for the selected meter o The user selects the future horizon (in months) to view expected failures ✓ The user views the expected failures per smart meter model for the selected future horizon • In the **“Critical Smart Meters Analysis” section**: o The user views and records the list of critical smart meters. o The user views and records the importance of the different attributes in the XGboost classifier. o The user views the map representation of the substations. • The user clicks on the red pins to view the critical smart meters in the relevant secondary substations.
Exception path(s)	Improper files format or data structures in the input files are detected and error messages are presented to the user highlighting the erroneous sections.
Post-condition	• In the **“End of Life Curves Analysis” section**: o Using the drop-down options the user selects the brand and model of a smart meter o The user views the EoL curve that is generated for the selected meter o The user selects the future horizon (in months) to view the number of expected failures per smart meter model • In the **“Critical Smart Meters Analysis” section**: o The user views and records the list of critical smart meters. o The user views and records the importance of the different attributes in the XGboost classifier. o The user views the map representation of the substations o The user clicks on the red pins to view the critical smart meters in the relevant secondary substations
Datasets required	• Smart meter historical data • Geodata of the secondary substations • Smart meter SFTP data
Output data	• In the **“End of Life Curves Analysis” section**: o The user validates that: ✓ The message “Limited Failure Numbers recorded” is printed for brand /models with not enough failures. ✓ The EoL curve is generated for the selected brand/model, if adequate number of failures are available o The user validates that expected failures per smart meter model for the selected future horizon are presented • In the **“Critical Smart Meters Analysis” section**: o The user validates that the list of critical smart meters is presented. o The user validates that the importance of the different attributes in the XGboost classifier is presented. o The user validates that the map representation of the substations is presented (with red pins indicating critical smart meters in the relevant secondary substations)
Related KPIs	KPI.AAM.01
Related pilot	Spanish pilot
Results of the experiment	

(reported in D6.2)
Qualitative analysis of the results
(reported in D6.2)

SP pilot TC1.8.1.2

Test case ID	TC1.8.1.2
Name	Baseline consumption forecast (SP pilot)
Timeframe	M33-M42
Targets	Forecast the baseline consumption for a particular consumer
Actors involved	• **HYP**: BFMS responsible partner • **ESTABANELL / ANELL / ETRA**: Asset operators at the Spanish pilot • **QUE**: Data Space operator
Assets & systems involved	• Assets at pilot sites, including EMS • BFMS • Data Space (Data Space Connector deployed at each participant site)
Triggering event	BFMS is automatically set to create a baseline consumption forecast on a periodical basis, for instance a day-ahead forecast
Pre-condition	• Communication of assets with EMS is established (BESOS for the Spanish) • Communication of EMS with BFMS is established (over the Data Space) • Sufficient and good quality data is received from the BFMS, including power consumption time series and where available user-defined constraints. • BFMS baseline calculation algorithm is available for the target asset types
Test case description	1. Data acquisition: Consumption data per asset and user preferences (optionally) are retrieved from HEMS/BEMS. 2. Data pre-processing: Retrieved data undergoes preprocessing for outlier detection and removal. 3. Baseline forecasting: the Flexibility Forecasting Module generates day-ahead baseline consumption values per asset using historical profiles and machine learning models. 4. Baseline storage: Forecasted baseline values are stored in the Profiling Storage & Retrieval Service for future use.
Exception path(s)	In case of insufficient data due to communication failure or data gaps (e.g., missing, or incomplete consumption data), BFMS could use historical averages.
Post-condition	A baseline forecast consumption profile is created pet asset and stored in the Profiling Storage and Retrieval Service. The baseline forecast is available through the Data Space for market bidding at the NODES platform.
Datasets required	Asset power consumption data from pilots
Output data	Baseline consumption forecast
Related KPIs	KPI.HEMS.01 KPI.HEMS.03
Related pilot	Spanish pilot

Results of the experiment
(reported in D6.2)

Qualitative analysis of the results
(reported in D6.2)

SP pilot TC1.8.2.2

Test case ID	TC1.8.2.2
Name	Flexibility consumption forecast (SP pilot)
Timeframe	M33-M42
Targets	Forecast the flexibility consumption for a particular consumer
Actors involved	• **HYP**: BFMS responsible partner • **ESTABANELL / ANELL / ETRA**: Asset operators at the Spanish pilot • **QUE**: Data Space operator
Assets & systems involved	• Assets at pilot sites, including EMS • BFMS • Data space (Data Space Connector deployed at each participant site)
Triggering event	BFMS is automatically set to create a flexibility consumption forecast on a periodical basis, for instance a day-ahead forecast.
Pre-condition	• BFMS flexibility calculation algorithm is available • A baseline consumption forecast has been created and stored in the Profiling Storage & Retrieval Service • Day ahead energy price timeseries available (optionally) • User-defined constraints have been retrieved (optionally)
Test case description	1. Baseline retrieval: BFMS retrieves the previously generated day-ahead baseline consumption forecast for each asset. 2. Market data retrieval: BFMS retrieves day ahead energy price timeseries if available. 3. Flexibility forecast: BFMS generates forecasted flexibility consumption values. 4. Flexibility Storage: Forecasted flexibility values are stored in the Profiling Storage & Retrieval Service for future use.
Exception path(s)	In case of unavailable baseline forecast, flexibility values cannot be generated. In case of missing market data, only user-defined constraints will be used.
Post-condition	A flexibility forecast consumption profile is created pet asset and stored in the Profiling Storage and Retrieval Service. The flexibility forecast is available through the Data Space for market bidding at the NODES platform.
Datasets required	Forecasted baseline energy consumption values for each asset
Output data	Flexibility consumption forecast
Related KPIs	• KPI.HEMS.03 • KPI.HEMS.04 • KPI.HEMS.05
Related pilot	Spanish pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

SP pilot TC1.8.3.2

Test case ID	TC1.8.3.2
Name	Dispatch of control signals to assets (SP pilot)
Timeframe	M33-M42
Targets	Dispatch control signal at the assets
Actors involved	• **HYP**: BFMS responsible partner • **ESTABANELL / ANELL / ETRA**: Asset operators at the Spanish pilot • **NODES**: NODES platform operator • **QUE**: Data Space operator
Assets & systems involved	• BFMS • Data space (Data Space Connector deployed at each participant site) • NODES platform • Assets at pilot sites, including EMS
Triggering event	Flexibility order is matched on the NODES platform
Pre-condition	• BFMS has generated forecasted baseline and flexibility consumption values per asset • DSO has submitted a bid on the NODES platform • Communication between BFMS, NODES platform and controllable assets is operational
Test case description	1. BFMS retrieves the forecasted baseline and flexibility values for each asset. 2. BFMS communicates forecasted baseline and flexibility consumption values to the NODES platform. 3. The NODES platform matches the flexibility order based on submitted bids. 4. BFMS receives order acceptance from the NODEs platform. 5. BFMS generates appropriate control sequences for each controllable asset based on the matched order. 6. BFMS dispatches control signal to each controllable asset over the Data Space.
Exception path(s)	In case there is a communication failure between BFMS and the NODES platform, control action will not be delivered. In case user interferes with the controllable asset, user preference overrides any control action.
Post-condition	Controllable assets receive control signals
Datasets required	Forecasted baseline and flexibility consumption values
Output data	Dispatched control signals to assets
Related KPIs	• KPI.HEMS.02 • KPI.HEMS.04 • KPI.HEMS.05 • KPI.HEMS.06
Related pilot	Spanish pilot

Results of the experiment
(reported in D6.2)

Qualitative analysis of the results
(reported in D6.2)

SP pilot TC1.10.2

Test case ID	TC1.10.2
Name	Using flexibility to enhance grid capacity and resiliency (SP pilot)
Timeframe	M33-M42
Targets	To evaluate the use of residential assets for grid services
Actors involved	• **ANELL**: DSO • **ESTABANELL**: Aggregator • **ETRA**: Smart Grid Tool/ETER • **HYP**: Technical FSP and BFMS • **NODES**: FMO
Assets & systems involved	• Residential assets • ETER managed by ETRA; data input: SCADA • Advanced Metering Infrastructure (AMI) data
Triggering event	Grid capacity issue due to new increased share of home PV plants
Pre-condition	• Assets are identified and confirmed participation • Preparation of asset and meter data • Grid replication
Test case description	1. DSO monitors its grid through the ETER platform and foresees a future congestion or over/under-voltage which could be relieved with flexibility activation 2. DSO submits buy order on NODES platform indicating necessary volume and price it is willing to pay 3. BFMS forecasts the baseline and available flexibility upon receiving asset and meter data of the controllable assets 4. FSP submits sell offer to offer flexibility indicating available flexibility volume and desired price 5. The market applies continuous market clearing using pay-as-bid. If volume and price correspond the orders will be matched, either entirely or partly. Otherwise, the orders remain unmatched and the DSO and/or FSP can submit a new adjusted offer 6. In case of a trade, the FSP and the DSO have entered a binding contract. The FSP is obliged to deliver the flexibility as agreed by the trade. 7. The FSP ensures dispatch of flexibility 8. NOT tested: validation and settlement, hence the actual market operation is finalized for this pilot and can be repeated accordingly.
Exception path(s)	N/A
Post-condition	Pilot test case is NODES BAU without any further developments. Evaluation aspects: • Local flexibility as a grid service – Impact and efficiency • Price formation (to the extent possible) • End-prosumer feedback regarding demand-side flexibility
Datasets required	• Smart meter and submetering data • Asset baseline power consumption forecast per portfolio by FSPs • Simplified grid infrastructure for testing • Asset data (type of asset, location, installed capacity)
Output data	• Price data (though depending on real prices) • Data on flexibility activated (volume, asset types, clients)
Related KPIs	• KPI.HEMS.02 • KPI.HEMS.03 • KPI.FM.03 • KPI.FM.04

Related pilot	Spanish pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

SP pilot TC4.1.1

Test case ID	TC4.1.1
Name	Topology detection ability
Timeframe	M33-M42
Targets	The target is to identify the inaccuracies on the topological models of the DSO by analyzing the data received from the available network sensors and checking its compatibility with the calculated state estimation.
Actors involved	• **ANELL**: Grid operator, historical and real-time data provider • **ETRA**: ÉTER technology provider, with a functionality to detect topology
Assets & systems involved	• ÉTER (which includes a topology identification module) • SCADA (P, Q, V, I) • AMI system (P, Q, V, I)
Triggering event	Periodically, after grid state is estimated, results are analysed and compared with real measurements received afterwards. For the test, inaccuracies will be introduced in the topology
Pre-condition	• Topology is known, (even though it might be inaccurate) • "Theorical" grid measurements obtained by the state estimation process • Real grid nodes measurements available, not in real time, but with some minutes/hours of delay. These measurements will be obtained by using the test cycle reading capability of PLC networks

Test case description	• Errors will be manually introduced in the topology: False location of smart meters and false position of switches
	• Real time estate estimation is done by calculating pseudo-measurements for the unknown values of P & Q in the network.
	• In this scenario, there are no unknown measurements, because the process is calculated after the smart meters have sent its measurements.
	• With the data received from the smart meters and the data stored from the SCADA, grid state is estimated. In this case the level of confidence of the measurements is very high, as there are no pseudo/measurements involved in the process
	• Two things could happen:
	  o With all these conditions, the actual measurements can be inferred so that they are mathematically coherent, and power flows can be calculated.
	  o Not a valid set of measurements can be inferred, probably due to excessive power losses or out-of scale measurements
	• In case the state estimation fails, different things could explain this situation:
	  o There might be not-logged connections impacting the power flow results (illegal connections). This is evaluated in the TC4.2.1
	  o There might be inaccuracies in the topology like not properly logged switch statuses, impacting the power flow results. This case will be evaluated in this TC
	• ETER will automatically calculate power flows with different grid configurations and compare the results to check if they better match the real measurements.
	• In case a grid configuration provides more accurate results than the current configuration. The user is warned with a potential topology error detected.

	• For the experiment, different inaccuracies will be manually included in the topology (fake switch positions, false locations of smart meters), and the accuracy of the process will be evaluated by its capacity to identify and pinpoint these problems • A report with the potential set of errors detected will be generated for the DSO to check
Exception path(s)	N/A
Post-condition	ETER should display a message with the possible incorrect status of the topology. This must match the error introduced for the test
Datasets required	• Power curves (P,Q, V, I) of the required smart meters with 60 mins granularity (1 year) • SCADA measurements (P,Q, V, I) • Status of the topology in the analysed period
Output data	Report of the topology changes
Related KPIs	KPI.SP.01
Related pilot	Spanish pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

SP pilot TC4.2.1

Test case ID	TC4.2.1
Name	Non-technical losses detection accuracy
Timeframe	M33-M42
Targets	To detect potential theft attempts in the grid
Actors involved	• **ANELL**: Grid operator, historical and real-time data provider • **ETRA**: ÉTER technology provider, with a functionality to detect Non-Technical Losses
Assets & systems involved	• ÉTER (which includes a topology identification module) • SCADA (P, Q, V, I) • AMI system (P, Q, V, I)
Triggering event	DSO needs to determine the lines that are currently energized.
Pre-condition	• The format and location of the analysed LV network. Available network parameters must be: potential bus-branch configurations (topology), bus (generation/ load, installed capacity etc.) and branch parameters (line impedance, shunt elements etc.). SCADA measurements. • GIS access • ANELL should have an estimation of the inspection costs related to investigate and address a theft attempt and the cost of each kWh that is theft
Test case description	Before the own execution of the test, the DSO and ETRA must agree on an area in which the DSO well known that NTL appeared. Then: • ANELL must send to ETRA the topology data of the selected area and the historical data (P,Q,V,I) coming from the SCADA. • ETRA will run power flows with the data coming from the SCADA in order to produce a set of measurements (P,Q,V,I). • ÉTER must detect the discrepancies in the flows in the areas affected with the NTL. • Thus, ÉTER must tag the affected substation and provide an estimation of the specific area according to the smart metering data analysed. • While the previous steps serve to check the detection of the fraud (KPI.SP.04), After these steps, ANELL will validate the precision of the location (KPI.SP.02) and the economic benefits of solving the fraud (KPI.SP.03).
Exception path(s)	N/A
Post-condition	The grid operator receive**s** a signal (through ÉTER) whenever suspicious consumption patterns which may relate to a fraud are detected. They are given a location for the potential theft in a given branch of the network**.**
Datasets required	• Power curves (P,Q, V, I) of the required smart meters with 15 mins granularity (1 year) • Logs with the frauds in the analysed grid • SCADA measurements (P,Q, V, I) • Status of the topology in the analysed period
Output data	P, Q,V, I measurements from the SCADA and the AMI
Related KPIs	• KPI.SP.02 • KPI.SP.03 • KPI.SP.04
Related pilot	Spanish pilot

Results of the experiment
(reported in D6.2)
Qualitative analysis of the results
(reported in D6.2)

SP pilot TC4.3.1

Test case ID	TC4.3.1
Name	Detection of unexpected island's ability
Timeframe	M33-M42
Targets	The detection of blown fused and pinpointing its exact location and phase through the monitoring of the voltage at end user level.
Actors involved	• **ANELL**: Grid operator, historical and real-time data provider • **ETRA**: ÉTER technology provider, with a functionality to detect unexpected islands.
Assets & systems involved	• ÉTER (which includes a topology identification module) • SCADA (P, Q, V, I) • Weather forecast (Open weather) • PLC concentrators
Triggering event	A fuse is blown
Pre-condition	• Topology is known • Historical LV SCADA measurements (P, Q, V, I) with sufficient granularity • LV network's PLC concentrators could be configured to interrogate a set of smart meters for obtaining real-time electrical measurements. This data is stored in a database.
Test case description	Before the own execution of the test, the DSO and ETRA must agree on a LV area in which a fuse blew of can be tripped for testing purposes. When fuse is blown, the information of the outage would eventually reach the DSO, normally by phone calls. When this happens, the test starts: 1) First, the point of delivery (household) affected is identified 2) The DSO access the ETER tool and selects the fault location option in the appropriate LV network 3) The DSO marks the points of delivery affected by the outage. 4) The DSO clicks the button to locate fault. 5) The system provides an interrogation list for smart meters and presents it as a result 6) The interrogation list is configured in the test cycles of the DSO LV concentrator 7) Smart meters are interrogated in order and will eventually provide results. a. In case the smart meters interrogated are also affected by the outage (same phase of the fuse blown), they will not answer. b. The smart meters in the same line but different phase, will report unbalance voltages and c. Not affected smart meters will answer with regular measurements. 8) DSO introduces these measurements in the ETER tool, 9) The ETER tool will provide the most likely location of the blown fuse With the data extracted from each unitary test, ETRA will be able to analyze the accuracy, the F1 score and the detection time.
Exception path(s)	If no detection is done, more data is needed and ÉTER will request additional smart meters to be included in the interrogation cycle. This process will repeat iteratively until the fault location can be unambiguously detected.

Post-condition	The potential location of the blown fuse is stored in the database and it is displayed through the ÉTER tool
Datasets required	• Historical LV SCADA measurements (P, Q, V, I) with 15-minute granularity. • Smart meter data from the analyzed period. • Status of the LV topology in the analysed period.
Output data	Report about the location of the fault and how ÉTER reached that conclusion
Related KPIs	• KPI.SP.05 • KPI.SP.06
Related pilot	Spanish pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

SP pilot TC4.4.1

Test case ID	TC4.4.1
Name	Critical point detection ability
Timeframe	M33-M42
Targets	The aim of this tool is to evaluate the sections of the LV network that are more fragile or critical given the current network topology.
Actors involved	• **ANELL**: Grid operator, historical and real-time data provider • **ETRA**: ÉTER technology provider, with a functionality to detect critical points.
Assets & systems involved	• ÉTER (which includes a topology identification module) • SCADA (P, Q, V, I) • Weather forecast (Open weather)
Triggering event	The DSO starts a power flow scenario calculation in ETER tool
Pre-condition	Topology is known
Test case description	Firstly, it is needed to create a LV network scenario with ÉTER. To make this scenario different options are available: • An empty scenario can be selected with no P & Q stablished. • A scenario can be created from the status of the grid in a past period. For this period, the state estimation must have been calculated successfully • A scenario can be created from the current grid status, after the current state is estimated estimation. • A scenario can be created from a forecasted grid status (for a near future timestamp) In the generated scenario, the active and reactive power of each load can be stablished, as well as the status of the different grid switches. The idea is to modify the parameters of the assets located in the most critical parts of the grid to see the impact of these changes. The protections can also be changed to simulate the status of line tripping Then, the second part of the test will consist of the following: • ETER will run power flows in the scenario according to the new P and Q set points and grid configuration • Security analysis will be performed on the power flow results: o Congestion in cable sections. o Voltage profile variations • Incorrect protection settings via short-circuit current variations
Exception path(s)	In case of incorrect or infeasible power flows, the calculation will not converge, and an error will be raised.
Post-condition	The results of the calculations will be presented in the ETER tool for the operator to analyse and take informed decisions.
Datasets required	• Historical LV SCADA measurements (P, Q, V, I) with 15-minute granularity. • Smart meter data from the analyzed period. • Status of the LV topology in the analyzed period.
Output data	Report about potential areas and points that might be affected by the problems considered.
Related KPIs	KPI.SP.07
Related pilot	Spanish pilot
Results of the experiment	

(reported in D6.2)
Qualitative analysis of the results
(reported in D6.2)

SP pilot TC4.5.1

Test case ID	TC4.5.1
Name	Improving the grid infrastructure, using grid planning methodologies, while increasing RES integration
Timeframe	M33-M42
Targets	Identify the best upgrades in the system that maximize the RES capacity. The DSO will set in the user interface (UI) the necessary settings, like budget constraints and flexibility constraints and perform planning with a goal to maximize RES penetration. The DSO will view the list of the upgrades via the UI of the network planning tool, and their associated costs. The maximum RES capacity, according to the current limits in the lines and voltages in the buses, is also presented to the DSO, via the GUI of the tool.
Actors involved	• **ANELL**: DSO, user of the network planning tool • **ICCS**: Developer of the network planning tool
Assets & systems involved	• Software: Network planning tool • Hardware: ICCS server hosting the software • System topology (excel format) • Historical data of substation loading • Types of lines considered for upgrade
Triggering event	After uploading all the necessary files required and selected the desired settings, the DSO utilizes the network planning tool by selecting the option for "Maximize RES capacity Optimization".
Pre-condition	• The optimisation problem for maximising the RES capacity has been formatted and integrated in the network planning tool • The UI for the network planning tool has been developed • All required input data has been collected: o topology data of the feeder under test, o latitude and longitude of the area, o demand data for a year with hourly resolution per secondary substation, o the power factor per secondary substation, o information on the lines that will be considered for possible upgrade
Test case description	**Setup steps:** • The user (DSO) has collected required data for input to the tool (system topology and load curves per secondary substation) • The user successfully logs in the planning tool **Execution steps:** • In the **"Power Flow" Section**: o In the Topology field the user provides the excel file containing the topology data of the feeder under test. If loops are in the distribution network the user is asked to select which line is de-energized o In the power curves field, the user provides the CSV file that contains the demand data for a year with hourly resolution per secondary substation o In the cosφ field, the user provides the CSV file that contains the power factor per secondary substation o The user selects the horizon in years to run the analysis of power flow (and a multi-year optimization) and the load growth rate to be considered o In the "Select PV locations" field, the user selects the location of future PV installations, the year that they will be installed and the nominal power in kW o The user clicks on the "Calculate" tab to proceed with

	the power flow analysis. The user should then click on 'Optimization'
	• In the **"Optimization" section**:
	  o In the "line types" field, the user uploads a CSV file with the lines that will be considered for possible upgrades
	  o In the "Optimization Goals" field, the user selects 'Investment Deferral' as the optimization goal
	  o In the "Economic Parameters", the user sets the costs to be considered by the optimization formulation
	  o In the "Flexibility Parameters", the user defines the maximum flexibility by RES, the RES Power Factor Limit and the Maximum demand flexibility
	  o Then, the user clicks on the 'Calculate' button
	Post-execution steps:
	• In the **"Optimization Results"**:
	  o A list of the optimal upgrades is presented and their associated costs
	  o The maximum RES capacity according to the current limits in the lines and voltages is also presented with the hosting capacity presented per secondary substation

Exception path(s)	Improper files format or data structures in the input files are detected and error messages are presented to the user highlighting the erroneous sections.
Post-condition	The network planning tool allows an increment in the RES penetration in the examined network. Additionally, the tool successfully outputs the required upgrades in the grid in order to achieve the relevant increment in RES penetration.
Datasets required	• topology data of the feeder under test in excel format • latitude and longitude of the region • demand data for a year with hourly resolution per secondary substation • the power factor per secondary substation • information on the lines that will be considered for possible upgrade
Output data	• A list of the optimal upgrades is presented and their associated costs. • The maximum RES capacity according to the current limits in the lines and voltages is also presented with the hosting capacity presented per secondary substation.
Related KPIs	KPI.GPO.04
Related pilot	Spanish pilot

Results of the experiment
(reported in D6.2)

Qualitative analysis of the results
(reported in D6.2)

10.1.4 Slovenian pilot site test cases

SI pilot TC1.2.3

Test case ID	TC1.2.3
Name	NILM identification ability (SI pilot)
Timeframe	Before 17th Nov 2025 (M34): completed and tested integration of Reduxi device into NILM system Dec. 2025, Jan. 2026 (M36, M37): testing with citizens involved in the test
Targets	Analyse the ability of the NILM module to identify the different loads of a households using just the RT smart meter data as an input
Actors involved	• **Ambit**: provides the consumption data from Slovenian pilot • **ETRA**: NILM developer
Assets & systems involved	• Smart meter • Consumption sensors of larger appliances (e.g. EV charger, Heat pump, PV power plant) • Reduxi as a smart home gateway to provide RT data • NILM module
Triggering event	The ESCO or the retailer aims to provide new features to their clients, offering them the possibility to know their disaggregated consumption per asset without need of submetering.
Pre-condition	• Have a small batch of households to validate NILM results • Know the assets installed in each household
Test case description	Before the own execution of the test, the pilot site and ETRA must agree on the timeframe of the test. It has been agreed that the implementation would be completed by 17th of Nov. Afterwards, the testing with citizens will take place. • The smart home gateway must send the data from the smart meter to the NILM module during the defined periods. It should also store the data from the sensors, • The NILM module will be running and storing the RT data coming from the smart home gateway of the analysed period. After each period • The smart home gateway must send the data stored from the submeter sensors to ETRA, • Then, it will be possible to compare the disaggregation coming from the NILM and the data from the sensors and calculate the precision, the recall and the F1 score of the results, • A survey will be performed, asking citizens about their subjective evaluation of NILM. The questions will be about accuracy as well as about the interest in such a solution.
Exception path(s)	In case of complexity of integration of the submetering sensors, only subjective estimation of the results will be performed
Post-condition	NILM identification ability is evaluated, allowing assessment of model effectiveness under different day types and assets
Datasets required	Smart meter (P, Q) and submetering (P) pilot data with 1 min granularity from 1 month to make some training of the NILM algorithms (DS.SL.01)
Output data	• Smart meter data (P, Q) with 1 min granularity • Submetering data curves (P) with the same granularity as above • Citizen's feedback in real-time or post test
Related KPIs	KPI.NILM.01
Related pilot	Slovenian pilot
Results of the experiment	

(reported in D6.2)
Qualitative analysis of the results
(reported in D6.2)

SI pilot TC1.3.1

Test case ID	TC1.3.1
Name	State estimation calculation (SI pilot)
Timeframe	M34-M42
Targets	The target is to increase DSO grid observability, especially in LV networks
Actors involved	• **EL/EP**: Grid Operator, providing historical and real-time data • **ETRA – ETER**: technology provider, with state estimation calculation functionality
Assets & systems involved	• ÉTER (which includes the topology of the grid) • SCADA (P, Q, V, I) • AMI system (P, Q, V, I) • Existing Slovenian state estimation system (for comparison) • Weather forecast provider (Open Weather)
Triggering event	The process is continuously running
Pre-condition	• Historical load and generator measurements • Topology model of the grid (MV & LV) • Access to (near) RT measurement data gathered from the field: conventional (voltage magnitude, power flows/ injections delivered by SCADA). • Access to weather data (temperature, sunlight)

Test case description	The state estimation is continuously running and performing two main subprocesses:
	• The data gathering sub process is responsible of receiving (or retrieving) the available and relevant assets' measurements and store them in the system database. These data are heterogeneous in:
	  o Nature (type) of the measurements obtained
	  o Retrieving/receiving mechanism
	  o Granularity
	  o Distance from current timestamp. Some measurements are received in near real time (SCADA), whilst other could arrive delayed up to a month (smart meters)
	• The estimation sub process will consider all data stored in the system database and will:
	  o For all grid energy supply or delivery points with no real time measurements available, estimate the P & Q based on historical measurements, weather conditions, calendar and other exogenous variables. This data is usually known as pseudo-measurements
	  o Estimated pseudo-measurements and real time measurements will be combined and power flow will be calculated. Since pseudo-measurements are not totally accurate, power flow will most likely not converge.
	  o A certain level of confidence is given to each measurement, having the real time SCADA measurements the highest and pseudo-measurements the lowest.
	  o A mathematical process is applied to modify the initial set of measurements so that at the end they are mathematically correct from the point of view of its power flows, and at the same time the changes applied are minimized and proportional to the level of confidence of the measurement.
	• Security analysis is applied to the estimated power flow (real time and forecasted) and results are stored
	• Estimation will be compared with estimation provided by the

	Slovenian state estimation system, and with the smart meter values eventually received from the meters
Exception path(s)	There could be situations with not enough data to accurately estimate the loads and calculate the power flow. This will be warned to the end user and logged
Post-condition	The measurements estimated of the network elements are obtained and displayed in the topology representation of ÉTER. Also, the security problems are presented
Datasets required	• Power curves (P, Q) of the required smart meters with 15 mins granularity in the analysed period • Real time voltage and current of some selected smart meters (in certain periods) to assess state estimation accuracy • Substation measurements for buses and feeder: P, Q, V & I • Weather data from the analysed period • Status of the topology in the analysed period • State estimation calculation results by the Slovenian DSO EMS (external system), for comparison
Output data	Estimated P, Q, V, I from all grid nodes
Related KPIs	KPI.SE.02
Related pilot	Slovenian pilot

Results of the experiment
(reported in D6.2)

Qualitative analysis of the results
(reported in D6.2)

SI pilot TC1.5.1

Test case ID	TC1.5.1
Name	Long term asset management for smart metering equipment of DSOs (SI pilot)
Timeframe	M33-M42
Targets	DSO performs end-of-life assessment of smart meters and critical smart meter detection using the long-term module of the advanced asset management tool
Actors involved	• **EL/EP**: DSO, user of the asset management tool • **ICCS**: Developer of the asset management tool
Assets & systems involved	• Server hosting the database and the Advanced Asset Management tool • DSO Smart meters data collection system for the extraction of measurements (AMI) • DSO asset management system: for the extraction of smart meter installation and replacement data • Software: Asset Management Tool
Triggering event	After uploading all the necessary files required and selecting the desired settings, the DSO utilizes the asset management tool to view the EoL of smart meters, expected failures per smart meter models, and critical meters in the network.
Pre-condition	• Smart meter historical measurement data are automatically uploaded to the SFTP server • All required information for the smart meters has been collected: o installation/replacement data o MV/LV substations the smart meters are connected to o geodata (latitude, longitude) of secondary substations (optional) • Operational module for the calculation of EoL curves (and predictions of failures based on them) • Developed machine learning model for the identification of critical smart meters • Deployed GUI for the long-term module of the asset management tool
Test case description	**Setup steps:** • The DSO user has collected all required data for input to the tool • Interface and data upload to SFTP server has been tested. **Execution steps:** • The DSO user successfully logs in the Grid Management Software and selects under "Asset Management – Smar Meters the "EoL Curves & Critical Meters Analysis" tab. o In the **"Smart Meters Data Import" section**, the user (DSO) uploads historical data about the smart meters (location, IDs, installation, meter point, etc.) in CSV format[1] o In the **"Critical Smart Meters Analysis" section**, the user uploads a CSV file containing the geodata of the secondary substations to view the calculated critical smart meters on map. **Post-execution steps:** • In the **"End of Life Curves Analysis" section**: o Using the drop-down options the user selects the brand and model of a smart meter ✓ If not enough failures have occurred, i.e. less than 1% of the

[1] This file should include a row per smart meter that includes information about the metering point, the secondary substation that it belongs to, the installation date, the brand and the model, etc.

	total population, in a specific brand/model then the message "Limited Failure Numbers recorded" is printed in the interface ✓ If adequate number of failures have occurred, the user views the EoL curve that is generated for the selected meter o The user selects the future horizon (in months) to view expected failures ✓ The user views the expected failures per smart meter model for the selected future horizon • In the **"Critical Smart Meters Analysis" section**: o The user views and records the list of critical smart meters. o The user views and records the importance of the different attributes in the XGboost classifier. o The user views the map representation of the substations. o The user clicks on the red pins to view the critical smart meters in the relevant secondary substations.
Exception path(s)	Improper files format or data structures in the input files are detected and error messages are presented to the user highlighting the erroneous sections.
Post-condition	• In the **"End of Life Curves Analysis" section**: o Using the drop-down options the user selects the brand and model of a smart meter o The user views the EoL curve that is generated for the selected meter o The user selects the future horizon (in months) to view the number of expected failures per smart meter model • In the **"Critical Smart Meters Analysis" section**: o The user views and records the list of critical smart meters. o The user views and records the importance of the different attributes in the XGboost classifier. o The user views the map representation of the substations o The user clicks on the red pins to view the critical smart meters in the relevant secondary substations
Datasets required	• Smart meter historical data • Geodata of the secondary substations • Smart meter SFTP data
Output data	• In the **"End of Life Curves Analysis" section**: o The user validates that: ✓ The message "Limited Failure Numbers recorded" is printed for brand /models with not enough failures. ✓ The EoL curve is generated for the selected brand/model, if adequate number of failures are available o The user validates that expected failures per smart meter model for the selected future horizon are presented • In the **"Critical Smart Meters Analysis" section**: o The user validates that the list of critical smart meters is presented. o The user validates that the importance of the different attributes in the XGboost classifier is presented. o The user validates that the map representation of the substations is presented (with red pins indicating critical smart meters in the relevant secondary substations)
Related KPIs	KPI.AAM.01
Related pilot	Slovenian pilot
Results of the experiment	

(reported in D6.2)
Qualitative analysis of the results
(reported in D6.2)

SI pilot TC1.5.2

Test case ID	TC1.5.2
Name	Short-term asset management for HV/MV and MV/LV transformers (SI pilot)
Timeframe	M34-M42
Targets	This test case will utilize the short-term module of the advanced asset management tool in order to provide information on the condition of transformers, performing Top Oil Temperature Anomaly detection & prediction. The designed short term asset management module will perform the following tasks: a) raise alarms, if needed, for specific transformer' components (according to the available measurements), b) present historical records of alarms c) predict possible critical conditions in the future and link them to a failure probability.
Actors involved	• **EL/EP**: DSO, user of the asset management tool • **ICCS**: Developer of the asset management tool
Assets & systems involved	• Transformers and transformer on-line monitoring systems • Software: Asset Management Tool • Server hosting the asset management tool and database.
Triggering event	The user (DSO) logs into the tool. The user can select to upload further historical data via the respective section and retrain the models. The user can see historical records of alarms in the historical data section and see the latest alarm status and future oil predictions in the real time section.
Pre-condition	• Established interface to the SFTP server to automatically upload the OLMS data daily. The OLMS data includes at least current measurement, top oil temperature and ambient temperature • Any further historical data to be provided in the UI is collected in the proper format (CSV) • Predictive models have been trained, using machine learning, considering the available historical data • Deployed GUI for the short-term module of the asset management tool
Test case description	**Setup steps:** • The DSO has collected all required data for input to the tool **Execution steps:** • The user (DSO) successfully logs into the Grid Management Software and selects the "Asset Management – Transformers" tab • In the **"Historical Data Import" tab**: o The user selects one of the registered assets o The user uploads a CSV file containing the historical OLMS data, either by dragging and dropping a file, or browsing to select a file from their system **Post-execution steps:** • In the **"Real Time Monitoring" tab**: o In *'Oil Anomaly Detection'*: • the user reports whether anomalies have been detected or not, as well as the colour of the relevant light – green/red) • the user, by viewing the relevant figure, reports if the model's output remains within an acceptable range, as defined by horizontal boundaries on the graph o In *'Top Oil Prediction'*: • The probability of failure and the 50 and 90 quantiles of top oil temperature forecast for the next six hours are shown • The user can download the historical logs for offline

	assessment
Exception path(s)	Improper files format or data structures in the input files are detected and error messages are presented to the user highlighting the erroneous sections
Post-condition	• In the **"Historical Data Import" tab**: o The preview of the data displayed in table format indicates that the file has been uploaded correctly • In the **"Real Time Monitoring" tab**: o In *'Oil Anomaly Detection'*: • It is displayed whether anomalies have been detected or not, as well as the colour of the relevant light – green/red • A figure is presented indicating whether the model's output remains within an acceptable range, as defined by horizontal boundaries on the graph o In *Top Oil Prediction'*: • The failure probability for the next 6 hours is displayed in the relevant table as well as a 50 and 90 quantile of top oil temperature forecast for the next six hours in a graph. • In the **"Historical Analysis" tab**: o The user sees the alarms for the selected period. o The user downloads the alarm logs in CSV format
Datasets required	Transformer historical monitoring data Transformer monitoring data from OLMS
Output data	Core operating measurements: • Top-oil temperature • Ambient temperature • HV current Bushing condition: • Capacitance: HV1/HV2/HV3 and LV1/LV2/LV3 • Tan-δ (dissipation factor): HV1/HV2/HV3 and LV1/LV2/LV3 Dissolved Gas Analysis (DGA): • H_2, CH_4, C_2H_2, C_2H_6, C_2H_4
Related KPIs	KPI.AAM.01
Related pilot	Slovenian pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

SI pilot TC1.6.2

Test case ID	TC1.6.2
Name	Topology identification (SI pilot)
Timeframe	M33-M42
Targets	The target is to determine both the connections and line impedances of the selected part of the grid.
Actors involved	• **EL/EP**: Grid Operator, providing historical and real-time data • **ETRA**: ÉTER technology provider, with a functionality to identify topology
Assets & systems involved	• ÉTER (which includes a topology identification module) • SCADA (P, Q, V, I) • AMI system • Slovenian estate estimation system
Triggering event	DSO needs to know how the components of the network are interconnected.
Pre-condition	• Historical electrical measurements (P, Q, V, I) from network assets, from SCADA or Slovenian state estimation system (anonymized) • General characteristics of the network to identify
Test case description	• The DSO sends to ETRA the historical data (P,Q,V,I) gathered from the SCADA or inferred from the state estimation software at DSO premises • ETRA uses this data to try to infer the grid topology from the raw values, using voltage correlation analysis between nodes. Resulting topology and confidence levels are returned • ETRA compares the topology estimated by the module with the one provided initially by the DSO to build the accuracy KPI
Exception path(s)	It may happen that the data provided does not contain enough information to identify the topology. In this case the process will return an error
Post-condition	After analysing all smart meter data and applying the techniques, the resulting topology will be returned in the format specified in the execution parameters.
Datasets required	• Power curves (P,Q, V, I) of the required smart meters with 15 mins granularity (1 year) • Status of the topology in the analysed period (for comparison)
Output data	Topology adjacency matrix, with the direct connections between grid nodes
Related KPIs	KPI.TI.01
Related pilot	Slovenian pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

SI pilot TC1.7.1

<table>
<tr><th>Test case ID</th><th>TC1.7.1</th></tr>
<tr><td>Name</td><td>Network planning tool to defer distribution network investments (SI pilot)</td></tr>
<tr><td>Timeframe</td><td>M33-M42</td></tr>
<tr><td>Targets</td><td>This test case will utilize the network planning algorithm in order 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.</td></tr>
<tr><td>Actors involved</td><td>• EL/EP: DSO, user of the network planning tool
• ICCS: Developer of the network planning tool</td></tr>
<tr><td>Assets & systems involved</td><td>Software: Network Planning Tool</td></tr>
<tr><td>Triggering event</td><td>The DSO utilizes the network planning tool, selecting the option for “investment deferral”</td></tr>
<tr><td>Pre-condition</td><td>• The algorithm for investment deferral has been in the network planning tool
• The GUI for the network planning tool has been developed
• All required input data has been collected:
o topology data of the feeder under test
o demand data for a year with hourly resolution per secondary substation
o the power factor per secondary substation
o information on the lines that will be considered for possible upgrade</td></tr>
<tr><td>Test case description</td><td>Setup steps:
• The user (DSO) has collected required data for input to the tool (system topology and load curves per secondary substation)
• The user successfully logs in the planning tool
Execution steps:
• In the “Power Flow” Section:
o In the Topology field the user provides the file containing the topology data (excel or CIM) of the feeder under test. If loops are in the distribution network the user is asked to select which line is de-energized
o In the power curves field, the user provides the CSV file that contains the demand data for a year with hourly resolution per secondary substation
o In the cosφ field, the user provides the CSV file that contains the power factor per secondary substation
o The user selects the horizon in years to run the analysis of power flow (and a multi-year optimization) and the load growth rate to be considered
o In the “Select PV locations” field, the user selects the location of future PV installations, the year that they will be installed and the nominal power in kW
o The user clicks on the “Calculate” tab to proceed with the power flow analysis. The user should then click on ‘Optimization’
• In the “Optimization” section:
o In the “line types” field, the user uploads a CSV file with the lines that will be considered for possible upgrades
o In the “Optimization Goals” field, the user selects ‘Investment Deferral’ as the optimization goal</td></tr>
</table>

	o In the "Economic Parameters", the user sets the costs to be considered by the optimization formulation o In the "Flexibility Parameters", the user defines the maximum flexibility by RES, the RES Power Factor Limit and the Maximum demand flexibility o in 'Battery Energy Storage System Parameters', the user selects the buses (if any) to consider storage options, and the storage system associated parameters o Then, the user clicks on the 'Calculate' button
Exception path(s)	Improper files format or data structures in the input files are detected and error messages are presented to the user highlighting the erroneous sections.
Post-condition	In the **"Optimization Results"**: • The user records the year indicated for the proposed investments
Datasets required	• topology data of the feeder under test • demand data for a year with hourly resolution per secondary substation • the power factor per secondary substation • information on the lines that will be considered for possible upgrade
Output data	• Year for the proposed investments as indicated by the planning tool for the scenario under study • Year that the investment would normally occur for the case without considering any flexibility (The user reruns this case adjusting the proper settings and compares the years of investments to calculate how many years the investments are delayed)
Related KPIs	• KPI.GPO.01 • KPI.GPO.02 • KPI.GPO.03
Related pilot	Slovenian pilot

Results of the experiment
(reported in D6.2)

Qualitative analysis of the results
(reported in D6.2)

SI pilot TC3.1.1

Test case ID	TC3.1.1
Name	Validation of location-level forecast accuracy for EV fleet baseline consumption
Timeframe	M34-M42
Targets	Evaluate the accuracy of short-term consumption forecasts for EV charging stations, aggregated at the location level (e.g., under a single transformer). The forecasts can support DSO use cases such as flexibility allocation, grid congestion mitigation, and time-sensitive tariff optimization
Actors involved	• **AVANTCAR:** EV fleet operator providing historical and real-time data • **UL**: forecast models provider, deployed at UL side • **SETUP**: helps with the evaluation, provides data received from AVANTCAR backend
Assets & systems involved	• Clusters of EV charging stations grouped by physical location • Forecasting models trained and deployed per location • SETUP's aggregator platform for data exchange
Triggering event	Forecasts are generated at fixed intervals (e.g., every 15 minutes) using the most recent aggregated EV charging data available at each location
Pre-condition	• Models trained on location-level data • Established communication with AVANTCAR (receiving up to date data from EV charging stations)
Test case description	This experiment tests the accuracy of short-term baseline forecasts for EV charging demand at the location level, where each location includes 2 to 10 charging stations. It evaluates how the number of charging stations, charging behaviour patterns, and temporal dynamics affect model performance. 1. Confirm that aggregated charging data from each location is received correctly (correct format, without missing data) 2. Generate baseline forecasts at regular intervals (e.g., every 15 minutes) for each location 3. Record actual measured values and corresponding forecasts 4. Analyse the forecasting accuracy using selected KPIs for two time horizons: a. Day-ahead b. 1-hour ahead
Exception path(s)	1b Aggregated data from EV charging stations is not being received • Halt the experiment • Investigate the data pipeline • Resume testing only once data integrity is restored 2b If the forecast generation fails (e.g. due to model or system errors) • Log the failure and analyse platform/model diagnostics. • If needed, retrain or redeploy the forecasting models. • Re-run the test from Step 2 after issue resolution.
Post-condition	Forecast accuracy at the location level is evaluated based on predefined performance metrics. The results allow comparison of model performance across locations and timeframes, supporting further tuning or model selection for operational use.
Datasets required	• DS.SI.01 (EV charging power) • DS.SI.04 (EV station metadata)
Output data	/

Related KPIs	KPI.SI.01
Related pilot	Slovenian pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

SI pilot TC3.1.2

Test case ID	TC3.1.2
Name	Validation of portfolio-level forecast accuracy for EV fleet baseline consumption
Timeframe	M34-M42
Targets	Assess the accuracy of baseline consumption forecasts for the aggregated EV fleet at portfolio level. These forecasts are intended to support participation in energy and balancing markets by providing reliable estimates of expected charging demand.
Actors involved	• **AVANTCAR**: EV fleet operator providing historical and real-time charging data • **SETUP**: Hosts and executes forecast models, receives incoming data from AVANTCAR • **UL**: Assists in defining and calculating KPI metrics for model evaluation
Assets & systems involved	• All EV charging stations included in the fleet portfolio • Portfolio-level forecast model • SETUP aggregator platform for data collection, model execution, and forecast management
Triggering event	Forecasts are generated for the full EV fleet portfolio at predefined intervals, aligned with energy market timelines (e.g., day-ahead and intra-day submission windows).
Pre-condition	• Models trained using aggregated portfolio-level data • Real-time and historical data from AVANTCAR are available and synchronized with SETUP platform
Test case description	This experiment evaluates the accuracy of portfolio-level baseline forecasts for total EV charging demand. It aims to validate the model's ability to produce reliable aggregate forecasts that can be used for energy market participation. The analysis also investigates consistency and potential bias (under- or over-forecasting) in the forecasts. 1. Generate baseline forecasts for the full EV fleet portfolio at defined intervals (e.g., hourly, day-ahead). 2. Record forecasted values alongside actual measured consumption for each time step. 3. Aggregate results over daily and weekly intervals to assess overall performance. 4. Apply selected KPIs to evaluate accuracy and detect bias. 5. Interpret results in the context of energy market applications (e.g., risk of forecast error in bidding).
Exception path(s)	1a No real-time data available from AVANTCAR • Stop forecasting generation • Diagnose the cause (data pipeline, communication error) • Resume testing only once data integrity is restored 1b Forecast model fails or does not execute properly • Check platform logs and model deployment status • If needed, redeploy the model or switch to backup versions • Re-run the test once the issue is resolved 4a Detected forecast deviation exceeds predefined error thresholds • Flag the result for further investigation • Reassess model configuration or input data quality
Post-condition	The forecasting model's accuracy at the portfolio level is evaluated using selected performance metrics across multiple time horizons. The results support assessment of model suitability for participation in energy and balancing markets.

Datasets required	• DS.SI.01 (EV charging power) • DS.SI.04 (EV station metadata)
Output data	/
Related KPIs	KPI.SI.01
Related pilot	Slovenian pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

SI pilot TC3.1.3

Test case ID	TC3.1.3
Name	Data collection reliability assessment for EV charging infrastructure
Timeframe	M35-M42
Targets	Evaluate the reliability of data collection from EV charging stations by quantifying the frequency and duration of outages, and the proportion of missing or delayed data points. The results will support improvements in forecasting accuracy and operational robustness.
Actors involved	• **AVANTCAR**: EV fleet operator providing real-time and historical data • **SETUP**: Monitors incoming data streams and logs availability metrics
Assets & systems involved	• EV charging stations in the fleet • SETUP aggregation platform • Data logging and monitoring module within the SETUP system
Triggering event	Monitoring begins when continuous data flow is established between AVANTCAR and SETUP and remains active throughout the defined test period.
Pre-condition	• EV charging stations are connected and transmitting data at an expected frequency • Data logging and timestamp monitoring are enabled on the SETUP platform

Test case description	This test case aims to assess the robustness of the EV charging data acquisition process. Reliable and continuous data collection is a critical foundation for downstream processes such as forecasting, flexibility estimation, and market bidding. Missing, delayed, or inconsistent data can lead to forecasting errors, incorrect flexibility calculations, and operational failures.
	The test will involve both real-time monitoring and historical data analysis to identify gaps, recurring issues, or infrastructure-related constraints.
	1. Configure the SETUP platform to log timestamps of received data from each charging station.
	2. Continuously monitor incoming data streams over the test period.
	3. Detect and record missing intervals, communication outages, and irregular reporting.
	4. Calculate key metrics:
	  • Percentage of missing data points
	  • Number and duration of outages
	  • Location-level data availability rates (portfolio level)
	5. Analyse historical data coverage and identify recurring reliability issues.

Exception path(s)	1a Data logging system fails or is misconfigured
	  • Stop monitoring process
	  • Investigate platform configuration and logs
	  • Restart the test and resume logging

Post-condition	A report is generated summarizing data availability metrics, outage patterns, and reliability issues. These findings will inform improvements in data infrastructure and support increased confidence in forecasting models and flexibility estimation.
Datasets required	• DS.SI.01 (EV charging power) • DS.SI.04 (EV station metadata)
Output data	/
Related KPIs	KPI.SI.08

Related pilot	Slovenian pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

SI pilot TC3.2.1

Test case ID	TC3.2.1
Name	Validation of household-level forecast accuracy for HEMS baseline
Timeframe	M35-M42
Targets	To validate the forecast accuracy of individual energy profiles at the household level using HEMS. Forecasts are generated separately for each connected asset (e.g., PV, heat pump, grid exchange), enabling asset-level performance analysis.
Actors involved	• **Amibit**: HEMS provider, supplies real-time and historical household-level data • **UL**: Develops and maintains the forecast models • **SETUP**: Helps with the evaluation, provides data received from Amibit backend
Assets & systems involved	• Reduxi HEMS devices installed at end-user households • Connected household assets (e.g., PV, heat pump, electric meter) • Forecast models deployed for each asset/channel • SETUP aggregator platform for data integration
Triggering event	Forecast models generate new predictions for each connected asset at defined intervals (e.g., every 15 minutes), based on the most recent household-level data.
Pre-condition	• Forecast models are trained and deployed for each relevant channel • Household HEMS devices are connected and sending valid data • The SETUP platform is operational and ready to receive and process asset-level data streams
Test case description	This experiment evaluates the accuracy of HEMS-based energy forecasts at the individual household level. Forecasts are generated for each connected asset (channel) within each Reduxi-equipped household. The Test case IDentifies forecasting performance across various asset types and informs further model tuning. 1. Confirm the availability of complete input data streams from each relevant HEMS channel. 2. Generate baseline forecasts for each channel and household using the trained models. 3. Collect actual power measurements for each asset over the same forecast intervals. 4. Compare forecasted and measured values using selected KPIs on a per-asset basis. 5. Analyse differences in model performance across asset types and households.
Exception path(s)	1a Missing or incomplete input data from HEMS channels • Flag affected households or assets • Skip forecast generation for the missing channels
Post-condition	Forecast accuracy is assessed for each household and each individual asset/channel. The results allow for asset-specific evaluation of model reliability and help prioritize further model development.
Datasets required	• DS.SI.02 (HEMS power per channel) • DS.SI.05 (HEMS channel metadata)
Output data	/
Related KPIs	KPI.SI.02
Related pilot	Slovenian pilot
Results of the experiment	

(reported in D6.2)
Qualitative analysis of the results
(reported in D6.2)

SI pilot TC3.2.2

Test case ID	TC3.2.2
Name	Validation of portfolio-level forecast accuracy for HEMS baseline
Timeframe	M35-M42
Targets	To validate the forecast accuracy of aggregated energy consumption across the entire HEMS portfolio. The goal is to assess the model's ability to predict the total load profile of all connected households, supporting potential future use in grid services or market participation.
Actors involved	• **Amibit** – Supplies household-level data from Reduxi HEMS units • **UL** – Develops and maintains portfolio-level forecasting models, hosts the models locally • **SETUP** – helps with the evaluation, provides data received from Amibit backend
Assets & systems involved	• Reduxi HEMS devices deployed across multiple households • Connected end-user energy assets (e.g., PV systems, heat pumps, grid meters) • Portfolio-level forecast models • SETUP aggregator platform for data collection
Triggering event	Forecasts are generated at regular intervals for the entire HEMS portfolio, based on the latest available data from all connected units.
Pre-condition	• Forecast models are trained and operational at the portfolio level • HEMS devices are transmitting valid data for all connected households • The SETUP platform is configured to receive and process data received from Reduxi units
Test case description	This experiment assesses the accuracy of portfolio-level forecasts for total energy consumption across all connected HEMS-equipped households. Unlike household-level forecasts, this test focuses on the aggregated view of the system. 1. Ensure a stable data stream from all participating Reduxi HEMS devices. 2. Generate baseline forecasts for the total portfolio load at each forecast interval. 3. Collect actual energy measurements for each household and channel. 4. Aggregate actual values to match the structure of the forecasted portfolio output. 5. Evaluate the forecast accuracy using portfolio-level KPIs 6. Analyse temporal trends and identify any bias or persistent deviations in the aggregated forecasts.
Exception path(s)	1a Incomplete data flow from individual households • Log affected units and exclude from aggregation if necessary • Flag the test period as partial • Resume full aggregation when data flow is restored
Post-condition	Forecast accuracy is quantified for the HEMS portfolio as a whole, enabling assessment of the model's suitability for aggregated services
Datasets required	• DS.SI.02 (HEMS power per channel) • DS.SI.05 (HEMS channel metadata)
Output data	/
Related KPIs	KPI.SI.02
Related pilot	Slovenian pilot

Results of the experiment
(reported in D6.2)
Qualitative analysis of the results
(reported in D6.2)

SI pilot TC3.2.3

Test case ID	TC3.2.3
Name	Data collection reliability assessment for HEMS portfolio
Timeframe	M35-M42
Targets	Evaluate the reliability of data collection from Reduxi HEMS devices across the entire portfolio by quantifying data loss, communication delays, outages, and reporting consistency per household and per channel. The objective is to identify systemic weaknesses and improve forecasting reliability and operational readiness.
Actors involved	• **Amibit**: Supplies data from Reduxi HEMS units installed in households • **UL**: Supports the design of the monitoring framework and the evaluation process • **SETUP**: Receives incoming HEMS data and performs continuous monitoring of data availability and integrity
Assets & systems involved	• Reduxi HEMS devices installed across households • Connected household assets and measurement channels • SETUP aggregator platform with logging and monitoring functionality
Triggering event	Monitoring begins once a stable and continuous data connection is established between the HEMS devices and the SETUP platform. Data transmission is expected at fixed intervals per channel (e.g., every 15 minutes).
Pre-condition	• Active data streams from Reduxi HEMS units across all required channels • SETUP platform is configured with logging and monitoring functionality to detect data loss, delay, or anomalies
Test case description	This experiment assesses the reliability of data collection across a portfolio of HEMS-equipped households. Accurate and timely data is critical for enabling downstream use cases, including forecasting, flexibility activation, and grid service participation. The test focuses on detecting data availability issues, communication reliability, and household- or channel-specific inconsistencies. 1. Define the expected data reporting frequency for each configured channel. 2. Monitor incoming data streams from all active households and channels over the duration of the test. 3. Record any missing intervals, reporting delays, or extended outages per channel and per household. 4. Calculate key reliability metrics 5. Identify recurring issues, poorly performing devices, or channel-level instability.
Exception path(s)	1a Logging fails or monitoring misconfigured • Pause monitoring activities • Reconfigure logging parameters and validate correct timestamping • Resume test from latest valid interval 2a Data from one or more HEMS units becomes completely unavailable • Flag affected units and exclude from analysis • Notify Amibit for troubleshooting and reactivation
Post-condition	A summary report is generated presenting reliability metrics per HEMS unit and channel, including data completeness, delay patterns, and outage durations. Results highlight systemic and device-level weaknesses and provide guidance for improving data infrastructure and modeling reliability.

Datasets required	• DS.SI.02 (HEMS power per channel) • DS.SI.05 (HEMS channel metadata)
Output data	/
Related KPIs	KPI.SI.08
Related pilot	Slovenian pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

SI pilot TC3.3.1

Test case ID	TC3.3.1
Name	Simulation-based validation of optimal selection algorithm
Timeframe	M34-M42
Targets	Validate the operation of an aggregator-side optimal selection algorithm designed to assign activation setpoints to flexible assets in response to simulated flexibility requests. The algorithm's main optimization objective is cost minimization, while simultaneously ensuring compliance with technical constraints (e.g., minimum activation duration, rest periods) and maintaining reliability of delivery. The test case aims to stress-test the algorithm under diverse conditions by varying portfolio composition, size, and configuration, ensuring robustness across different operating scenarios.
Actors involved	• **UL**: Developer of the selection algorithm; defines test scenarios and performs simulations • **SETUP**: validation of the results, scenario co-definition
Assets & systems involved	• Forecasted flexibility profiles derived based on real EV and HEMS data • Derived flexibility availability curves (per asset and portfolio). • Optimal selection algorithm • Asset metadata (e.g., max power, activation duration, rest requirements)
Triggering event	Each simulation is triggered by inputting synthetic flexibility requests, combined with asset baseline/flexibility forecasts and associated constraints.
Pre-condition	• Baseline consumption forecasts are available per asset (EVs and HEMS) • Flexibility availability is calculated based on those forecasts • Asset constraints and availability metadata are defined (e.g., max duration, rest times) • Multiple scenario definitions prepared, covering: o Different portfolio sizes (small, medium, large) o Different device mixes (EV-heavy, HEMS-heavy, balanced) o Different configuration parameters (e.g., high vs low flexibility, strict vs relaxed constraints) o Varying flexibility request patterns (size, timing, duration)
Test case description	This test case evaluates how well the optimal selection algorithm can minimize cost while fulfilling flexibility requests under varying and sometimes challenging portfolio conditions. The algorithm must allocate setpoints to available assets in a way that respects technical and reliability constraints. Execution steps (per scenario): 1. Load baseline forecasts (EV + HEMS) and derive flexibility curves. 2. Input scenario-specific portfolio, constraints, and flexibility requests. 3. Run the optimal selection algorithm to allocate setpoints. 4. Record outputs: selected assets, setpoints, fulfilment rate, total committed flexibility, cost. 5. Evaluate performance using KPIs (latency, fulfilment, constraint violations). 6. Store results for later analysis.
Exception path(s)	1a Algorithm fails to find a feasible solution • Log the scenario inputs and failure reason • Review constraints or asset pool size • Adjust scenario parameters if needed

	2a Inconsistency between total committed power and requested power • Investigate whether constraints (e.g., rest time or insufficient capacity) caused under-fulfilment • Log affected scenarios for future algorithm tuning
Post-condition	For each scenario, the selection algorithm's decisions are recorded and evaluated. A performance report is generated, including all KPIs and any identified constraint violations or inconsistencies. Results support validation of the algorithm's effectiveness and guide further improvements.
Datasets required	• DS.SI.06 (Flexibility bid scenarios) • DS.SI.07 (Asset constraints and parameters)
Output data	/
Related KPIs	• KPI.SI.03 • KPI.SI.04
Related pilot	Slovenian pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

SI pilot TC3.3.2

Test case ID	TC3.3.2
Name	Market selection optimization for flexibility provision
Timeframe	M34-M42
Targets	To validate that the aggregator platform correctly selects the most profitable market (e.g., Day-Ahead, TSO markets or combination) for flexibility activation based on forecasted flexibility availability and market price signals. The aim is to test the decision-making logic and its effectiveness in maximizing expected revenue under different simulated market conditions.
Actors involved	• **AVANTCAR**: Provide historical and real-time data used for forecasting flexibility (from EVs) • **SETUP**: Generates forecasts and executes the market-selection algorithm
Assets & systems involved	• Forecasted flexibility profiles from EV fleet • Market data inputs (price forecasts for DA and TSO markets) • Market-selection module integrated in the SETUP aggregator platform
Triggering event	After flexibility forecasts are generated for the next 24 hours, and corresponding market prices are available, the aggregator platform triggers the market-selection algorithm to evaluate revenue potential and decide which market to target.
Pre-condition	• Valid and complete flexibility forecasts are available for the next 24 hours • Hourly price signals are available for all relevant markets (DA, TSO)
Test case description	This test case evaluates the aggregator platform's ability to make optimal market participation decisions by comparing the expected revenues from different flexibility markets. The platform uses forecasted flexibility and hourly price curves to simulate which market would generate the highest expected revenue under given conditions. Each scenario simulates one day of operation and includes a full-day forecast of available flexibility and price signals from DA, ID, and TSO markets. The market-selection module computes the expected revenue for each market based on the quantity and timing of flexibility and selects the most profitable one. 1. Generate DA flexibility forecasts 2. Collect and simulate hourly price forecasts for all relevant markets (DA, TSO) 3. Input forecasts and price signals into the market-selection algorithm 4. Run the algorithm to: a. Estimate potential revenue for each market b. Select the market with the highest expected revenue 5. Log: a. Market selected b. Expected revenue c. Revenues for other non-selected opt 6. Calculate determined KPIs
Exception path(s)	1a Missing or corrupted forecast data (flexibility or market price) • Run the forecasting module again • If this does not work, flag the test as invalid
Post-condition	A report is generated showing, per day, the market chosen, estimated revenues, and whether the choice was optimal.
Datasets required	• DS.SI.01 (EV charging power)

	• DS.SI.03 (Market price forecasts)
Output data	/
Related KPIs	KPI.SI.05
Related pilot	Slovenian pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

SI pilot TC3.3.3

Test case ID	TC3.3.3
Name	EV charging station operation – day-ahead participation
Timeframe	M35-M42
Targets	Test cost-optimized charging control of a selected EV charging station, using DA market price forecasts to determine the best time windows for charging, aiming to minimize energy cost while maintaining usability.
Actors involved	• **AVANTCAR**: Provides real-time and historical EV charging data; applies the charging schedule to the station • **SETUP**: Hosts the forecast models and optimization engine; recommends charging schedule
Assets & systems involved	• EV charging station (operated and controlled by AVANTCAR) • SETUP aggregator platform with: o Forecast module for energy prices o Optimization engine for computing charging schedule • Market data (price forecasts)
Triggering event	On designated test days, the cost-optimized charging schedule is generated one day in advance (D-1) using price forecasts, and sent to AVANTCAR as recommended charging schedule.
Pre-condition	• Charging station must be operational and controllable via AVANTCAR • Forecasting and optimization modules deployed and configured • Historical market price data and price forecasts available
Test case description	This test case assesses the real-world operation of an EV charging station scheduled according to cost optimization logic using Day-Ahead electricity market price forecasts. The optimization algorithm selects low-price periods for charging, subject to operational constraints (e.g., time windows, charging duration, minimum state of charge if available). The results will be compared to a baseline representing non-optimized (e.g., immediately start charging) behaviour to assess economic benefits. 1. Run price forecasts for the next day 2. Execute the charging optimization algorithm to generate a cost-minimizing charging schedule 3. The optimized schedule is sent to AVANTCAR, which applies the schedule (e.g., setpoints, time windows) to the selected EV charging station. 4. SETUP monitors the actual charging session using measurement data retrieved via the AVANTCAR API. 5. SETUP simulates a baseline charging profile for the same session. 6. SETUP compares the actual energy cost incurred under optimized charging to the simulated baseline cost. 7. Calculate the KPIs
Exception path(s)	1a Forecasting and optimization modules fail • Log scenario for exclusion from cost savings analysis 2a Control failure with charging station • Notify operator, investigate connectivity or device issue
Post-condition	The EV charging session is completed successfully using the optimized schedule. A post-analysis report compares actual incurred electricity costs against a baseline, validating the effectiveness of market-based smart charging.
Datasets required	• DS.SI.01 (EV charging power) • DS.SI.03 (Market price forecasts)

Output data	EV charging station status, power
Related KPIs	KPI.SI.06
Related pilot	Slovenian pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

SI pilot TC3.3.4

Test case ID	TC3.3.4
Name	Reduxi HEMS tariff system economic optimization
Timeframe	M35-M42
Targets	Test the performance of the Reduxi HEMS tariff optimization algorithm with the goal of reducing electricity costs for residential users under the Slovenian tariff scheme.
Actors involved	• **Ambit** – Provider and operator of Reduxi HEMS • Volunteer end-users – Participating households using Reduxi • **UL** – assists with monitoring and KPI calculation
Assets & systems involved	• Reduxi HEMS devices • Connected flexible devices (focussing on HPs) • Tariff optimization algorithm embedded in Reduxi • Tariff model with associated prices
Triggering event	Daily optimization trigger
Pre-condition	• Reduxi devices installed and operational at selected households • Anonymized household consumption measurement data • Access to applicable tariff information and pricing structure • Control integration in place for relevant devices • Mathematical model of HVAC devices
Test case description	The purpose of this test case is to verify if heat pumps are suitable devices for flexibility and whether Reduxi's optimisation can effectively lowers electricity costs by shifting energy consumption to cheaper tariff periods and preventing penalties for exceeding peak power limits. The focus of this test case analysis will be on heat pumps. The main reason for selecting heat pumps is their widespread installation and promotion across European households. They provide a cost-effective and largely untapped source of flexibility without compromising user comfort. The following steps will be performed as part of the test case: 1. Collect measurement data from HVAC device 2. Optimise heat pump activations to reduce costs in accordance with the new Slovenian tariff scheme. Under the Slovenian tariff scheme, the key parameter is the maximum consumption power within different time blocks. This value determines the network cost, which is the primary target of the optimisation. 3. To maintain user comfort within the test scope, the thermal inertia of the households will be estimated. It is assumed that the indoor temperature should not deviate from the ideal temperature by more than 0.5 to 1 °C. 4. The test case analysis will be performed offline, using real heat pump measurement data to simulate real-life conditions as accurately as possible. 5. The total costs will be compared against a baseline scenario (operation without tariff optimisation). 6. Key performance indicators (KPIs) will be calculated.
Exception path(s)	• Obtaining data failure – in case of issues obtaining real-life heat pump power data, we will reach out to the households and adjust the Reduxi systems to obtain the data reliably and accurately. • Low added value (low savings) after performing the optimization. In this case the analysis will address dynamic prices with a higher potential for savings.

Post-condition	The household receives a plan that reduces electricity cost while avoiding penalties. Actual performance is evaluated against a defined baseline.
Datasets required	• DS.SI.02 (HEMS power data per channel) • DS.SI.08 (Tariff structure)
Output data	HVAC status, active power (optionally outside temperature)
Related KPIs	KPI.SI.08
Related pilot	Slovenian pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

10.1.5 Separate, cross-platform test cases

Category	Test case ID	Test case name
Other	TC.PP.01	QR-enabled asset onboarding into HEMS/BEMS
	TC.DSP.01	Data exchange and identity management for non-intrusive load monitoring (NILM)
	TC.DSP.02	Data exchange and access control for HEMS/BEMS demand response optimization
	TC.DSP.03	Participant onboarding and secure initialization of HEMS/BEMS demand response strategy

TC.PP.01

Test case ID	TC.PP.01
Name	QR-enabled asset onboarding into HEMS/BEMS
Timeframe	M33-M42
Targets	Demonstrate seamless device recognition and integration with EMS platforms using standardized QR-based identification
Actors involved	• **Amibit** • **ETRA** • **ICCS** • **BSA**
Assets & systems involved	• HEMS/BEMS • Plug-and play tool (cloud-based repository for asset-data)
Triggering event	New energy flexibility asset data becoming available for sharing or querying by HEMS/BEMS providers
Pre-condition	• Knowledge of assets that are installed in pilot sites. • Relevant for HEMS/BEMS providers and FSPs, who intend to leverage the plug-and play tool for integration pathways of flexible energy assets.
Test case description	1. **Asset Registration** a. An Economic Operator (EO) submits static specifications of an energy-flexible asset (e.g., BESS, EVSE, PV SYSTEM, etc.) via the Bluesun web-app (UI or API). b. The system validates and stores the asset data in the repository. 2. **OPENTUNITY QR Code Issuance** a. Bluesun web-app generates an OT-QR code linked to that asset. b. If a Digital Product Passport (DPP) is available, pointing to a DPP-URL, that will be also included into the OT-QR. 3. **QR Code Scan at pilot site** a. During HEMS/BEMS setup at the pilot site, the end-user scans the OT-QR or DPP-QR code. b. The scan triggers an HTTP request to the Bluesun web-app's REST API. 4. **API Retrieval** a. Bluesun API returns the JSON payload with the asset's nominal characteristics and operational constraints. b. Data is validated against the required schema for HEMS/BEMS use. 5. **HEMS/BEMS Integration** a. The EMS ingests the received data and confirms it can use the specs to configure/control the device.

	6.KPI Evaluation a. QR Code Functionality Rate - Was the retrieval successful? b. Completeness Score - Did the asset provide sufficient specs?
Exception path(s)	NA
Post-condition	• Static energy flexibility data is securely exchanged between OPENTUNITY participants. • OPENTUNITY participants analyze information about the nominal characteristics of energy assets to determine their flexibility by scanning QR codes. • The QR codes accelerate Plug and Play recognition for flexibility devices by industrial players and market participants outside of the OPENTUNITY ecosystem.
Datasets required	Technical specifications of flexible assets (Nominal characteristics and Operational Constraints) per asset classification (e.g. BESS, EVSE, etc).
Output data	Nominal data access and user verification logs
Related KPIs	• KPI.PP.01 • KPI.PP.02
Related pilot	N/A – cross platform testing, not specific to any pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

TC.DSP.01

Test case ID	TC.DSP.01
Name	Data exchange and identity management for non-intrusive load monitoring (NILM)
Timeframe	M33-M42
Targets	Validate secure, sovereign data exchange of NILM datasets via the Federated Data Space
Actors involved	• **QUE**: Data Space operator • **HIVE**: Consumption data provider for Swiss pilot • **HYP**: Consumption data provider for Greek pilot • **ETRA**: NILM developer
Assets & systems involved	• Data Space Connector deployed at each participant site • OPENTUNITY Identity Management (IdM) • Wallet (Walt.Id) for verifiable credentials • NILM software platform and AMI systems
Triggering event	New NILM-related energy consumption data becomes available for sharing or querying within the Data Space
Pre-condition	• Participant onboarding completed with valid DIDs and verifiable credentials • Data Space connectors deployed and configured with participant templates (includes Wallet) • IdM services operational • NILM datasets registered in Federated Catalogue with defined access policies
Test case description	• Confirm onboarding of participants (platform owners) in Data Space using Onboarding UI • Request access and negotiate contract using Data Space Connector • Transfer NILM consumption datasets over secure channels adhering to data policies. • Validate data integrity and adherence to access permissions on receipt.
Exception path(s)	N/A
Post-condition	• NILM data is securely exchanged respecting sovereignty and access policies • Participants identities and roles are verified and authorized
Datasets required	Smart meter consumption time series data
Output data	• Access logs and authorization outcomes • Data transfer success/failure metrics • Credential issuance and verification logs
Related KPIs	• KPI.NILM.01 - F1 score of NILM model • KPI.DSP.01 - New participant onboarding time
Related pilot	N/A- cross platform testing, not specific to any pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

TC.DSP.02

Test case ID	TC.DSP.02
Name	Data exchange and access control for HEMS/BEMS demand response optimization
Timeframe	M33-M42
Targets	Data exchange of HEMS/BEMS demand response data and control signals via Federated Data Space
Actors involved	• **HYP**: BFMS responsible partner & asset operator at the Greek pilot • **AEM**: Asset operator at the Swiss pilot • **ETRA**: Asset operators at the Spanish pilot • **QUE**: Data space operator
Assets & systems involved	• Data Space Connector deployed at each participant site • OPENTUNITY Identity Management (IdM) • Wallet (Walt.Id) for verifiable credentials • Federated Catalogue service • HEMS/BEMS platforms and assets (EV chargers, storage, HVAC) • Flexibility market platform integration
Triggering event	Triggering of DR optimization or flexibility request campaign initiating data exchange and control signalling through the Data Space
Pre-condition	• Confirm onboarding of participants (platform owners) in Data Space using Onboarding UI • Connectors deployed and configured for interoperability • Flexibility datasets and service metadata registered in Federated Catalogue • Request access and negotiate contract using Data Space Connector • Access policies and roles defined • HEMS/BEMS platforms operational and connected to Data Space
Test case description	• Confirm participant onboarding and role assignment through onboarding UI and IdM • Register DR optimization service offerings and associated flexibility datasets in the Federated Catalogue • Trigger a DR optimization scenario from a Flexibility Market Operator or DSO via Data Space connector • HEMS/BEMS platforms retrieve DR signals and data respecting access controls • HEMS/BEMS execute DR optimization and generate flexibility bids • Exchange of flexibility bids and consumption adjustments occur securely via Data Space • Log all access, authentication, and data transfers for auditing • Collect performance and interoperability metrics during the DR event
Exception path(s)	N/A
Post-condition	• DR optimization data exchanged securely and flexibly with enforced data sovereignty • Flexibility bids generated and received within policy constraints • Audit logs available for all interactions • Federated Catalogue reflects current valid service offerings
Datasets required	• Historical data HEMS/BEMS consumption and flexibility data • DR signals and flexibility market instructions

Output data	• Access control and authentication logs • Data exchange success and error rates • DR optimization results and flexibility activation metrics • Catalogue query and update logs
Related KPIs	• KPI.HEMS.01 • KPI.DSP.01
Related pilot	N/A- cross platform testing, not specific to any pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

TC.DSP.03

Test case ID	TC.DSP.03
Name	Participant onboarding and secure initialization of HEMS/BEMS demand response strategy
Timeframe	M33-M42
Targets	Validate secure onboarding of prosumers and HEMS/BEMS systems via Federated Data Space
Actors involved	• **HYP**: BFMS responsible partner & asset operator at the Greek pilot • **AEM**: Asset operator at the Swiss pilot • **ETRA**: Asset operators at the Spanish pilot • **QUE**: Data space operator
Assets & systems involved	• Data Space Connector deployed at each participant site • OPENTUNITY Identity Management (IdM) • Wallet (Walt.Id) for verifiable credentials • Onboarding UI and Participant Management UI • HEMS/BEMS platforms supporting DR initialization
Triggering event	New prosumer or HEMS/BEMS participant initiates onboarding and DR strategy configuration via Data Space onboarding portal.
Pre-condition	• Centralized Trust Services, IdM and Wallet systems operational • Participant template configuration generation functionality available • HEMS/BEMS platform ready to accept DR profile initialization data • Valid policies pre-defined for onboarding and data access
Test case description	• Prosumer accesses Onboarding UI and submits registration details. • OPENTUNITY administrator reviews and approves participant request. • System generates participant template bundle including all needed configuration parameters. • Participant downloads bundle and deploys participant template on their infrastructure. • Connector authenticates with Trust Services (IdM) using DIDs and credentials. • HEMS/BEMS platform initializes DR strategy based on securely received initial settings profile via data space. • Participant Management UI monitors wallet contents and connector status. • All onboarding steps and data exchanges are logged and audited.
Exception path(s)	N/A
Post-condition	• Participant successfully onboarded with valid credentials • HEMS/BEMS DR strategy initialized securely via Data Space • Connector and Wallet operational and synchronized • Audit trail available for onboarding and initialization processes
Datasets required	• Participant registration and identity data • Initial DR profile configuration data • Credential and wallet metadata • Access policies and contract templates
Output data	• Onboarding logs and approval timestamps • Credential issuance and verification logs • Connector authentication and communication logs • DR initialization success/failure records
Related KPIs	KPI.DSP.01

Related pilot	N/A- cross platform testing, not specific to any pilot
Results of the experiment	
(reported in D6.2)	
Qualitative analysis of the results	
(reported in D6.2)	

10.2 Annex 2: Datasets

10.2.1 Greek pilot site datasets

Dataset DS.GR.01

Dataset ID	DS.GR.01
Data element	Network data of the Greek pilot distribution grid
Data description	Network data representing grid topology and parameters; obtained from utility-operated modelling systems; essential for topology identification (TI) and state estimation (SE) development and demonstration activities
Confidentiality	Confidential – includes sensitive grid data
Access	Provided as a one-time input by HEDNO during the initial configuration of the module
Source of data	HEDNO is responsible for collecting the necessary information via HEDNO's internal power system modelling software and geographic information system (GIS)
Measurement units	Branch impedance in Ohms or p.u., nominal transformer capacity in MVA, consumers' power factor (dimensionless), active/reactive power generation in MW/ MVar
Resolution	N/A – static information
Data reception frequency	Updates whenever grid changes take place (e.g., network expansion)
Time coverage	N/A – static representation of network
Data format	JSON
Related test cases	TC1.3.4, TC1.6.3, TC1.10.1

Dataset DS.GR.02

Dataset ID	DS.GR.02
Data element	Multi-source, conventional measurements collected from Greek pilot distribution grid
Data description	Measurement data collected from utility-operated existing (non-PMU) monitoring infrastructure; essential for offline training of topology identification (TI) and state estimation (SE) machine learning-based models
Confidentiality	Confidential - includes sensitive grid data and privacy-restricted customer information
Access	Provided as a one-time input by HEDNO during the initial configuration of the module
Source of data	• SCADA system at primary substation • AMI system devices installed at certain MV/LV transformers • AMR system units installed at MV customer premises HEDNO is responsible for collecting the necessary information. SCADA and AMR data are collected at HEDNO's telemetry centre, while AMI data is collected via a dedicated, separate platform.
Measurement units	• SCADA: bus voltage magnitude in Volts, branch current flow magnitude in Amperes,

	• AMI system: nodal voltage magnitude in Volts, nodal current injection magnitude in Amperes, active nodal power injection in kW, power factor (dimensionless) • AMR system: active nodal power injection in kW, reactive nodal power injection in kVar
Resolution	• SCADA: 15 min • AMI system: 1 min • AMR system: 15 min
Data reception frequency	N/A - provided as a one-time input
Time coverage	November 2023 – October 2024
Data format	CSV
Related test cases	TC1.3.4, TC1.6.3, TC1.10.1

Dataset DS.GR.03

Dataset ID	**DS.GR.03**
Data element	PMU measurements collected from Greek demo distribution grid
Data description	Measurement data collected from utility-operated PMU infrastructure; essential for real-time topology identification (TI) and state estimation (SE) services
Confidentiality	Confidential — provided by HEDNO; contains privacy-restricted customer information and sensitive, location-specific grid data
Access	Via MQTT
Source of data	Phasor data concentrator (PDC) at HEDNO premises collecting synchrophasors from PMU devices installed at strategically selected MV/LV transformers
Measurement units	Nodal voltage magnitude in V, current magnitude in A, voltage/current phase angles in ° (degrees)
Resolution	1 minute
Data reception frequency	1 minute
Time coverage	1 minute
Data format	CSV
Related test cases	TC1.3.4, TC1.6.3

Dataset DS.GR.04

Dataset ID	**DS.GR.04**
Data element	Real-time feeder operational data
Data description	Real-time operational data provided from DSO's SCADA
Confidentiality	Confidential – includes live operational measurements from distribution infrastructure, potentially sensitive to grid operator
Access	Data from the SCADA of the DSO are sent automatically to the RTTR tool through MQTT messages, where they are received in real time and stored directly in the RTTR database for processing and analysis
Source of data	DSO provides data infrastructure real-time sensor feed installed on line-segments

Measurement units	Line current (A)
Resolution	1 min
Data reception frequency	Real time
Time coverage	Covers the entire duration of the demonstration activities
Data format	JSON
Related test cases	TC1.4.2

Dataset DS.GR.05

Dataset ID	**DS.GR.05**
Data element	Topological data of the lines
Data description	Topological information that defines the physical and electrical characteristics of each line section of the lines processed by the tool
Confidentiality	Confidential – includes detailed information for distribution infrastructure, which is sensitive for the grid operation
Access	Data from the DSO, uploaded by the user via the UI for the RTTR module
Source of data	DSO users are responsible for collecting the necessary information using the available internal sources
Measurement units	• Latitude and Longitude in decimal degrees (EPSG:4326 standard) • mm (cross section) • Ω/km (electrical resistance/reactance) • A (maximum admissible current) • m (line length)
Resolution	N/A – static data
Data reception frequency	Uploaded on demand by the user – can be updated in case of reconfiguration of the examined line(s)
Time coverage	N/A – static data (covers the current structure of the examined grid)
Data format	CSV (UTF-8 encoding). Each row in the file represents a single section of the line, with the following required fields in the specified order: • line_section_name (string) • overhead_or_underground (string). • cross_section_sq_mm (float) • resistance_ohm_km (float) • reactance_ohm_km (float) • current_admissable_A (float) • line_length_m (float) • lat_start / lon_start / lat_end / lon_end (float) Detailed information for the format of the file is available in D5.4 – OPENTUNITY asset and planning developments (v2) [3]
Related test cases	TC1.4.2

Dataset DS.GR.06

Dataset ID	**DS.GR.06**

Data element	Historical current measurements
Data description	Historical measurement data that are used for the training of forecasting models and enriching the analysis. They include current measurements, average or per phase from any other source (e.g. SCADA) that are used for model training, analysis, and visualization within the tool
Confidentiality	Confidential – includes sensitive information for grid assets
Access	Data from the DSO. Uploaded manually by the user via the UI for the RTTR module
Source of data	DSO users are responsible for collecting the necessary information using the available internal sources, such as SCADA system or PMUs
Measurement units	Amperes (A)
Resolution	Minimum 1 hour
Data reception frequency	Uploaded on demand by the user
Time coverage	1/1/2020 - 30/06/2024
Data format	CSV (UTF-8 encoding), that includes the following three columns, in the specified order: • Timestamp in the format dd/mm/yyyy hh:mm:ss, in local time. • Measurement (string) • Value (float) Detailed information for the format of the file is available in D5.4
Related test cases	TC1.4.2

Dataset DS.GR.07

Dataset ID	**DS.GR.07**
Data element	Real-time line operational data
Data description	Real-time operational data from Dynamic Line Rating (DLR) sensors.
Confidentiality	Confidential – includes live operational measurements from distribution infrastructure, potentially sensitive to grid operator
Access	Uploaded automatically to RTTR's database through an API. Authorised User can access the data through the RTTR UI interface
Source of data	DSO provides data infrastructure real-time sensor feed installed on line-segments
Measurement units	Conductor Temperature (°C); Ambient Temperature (°C); Wind Speed & Direction (m/s, degrees); Line Current (A); Relative Humidity (%); Mechanical Tension (kN)
Resolution	15 minutes or hourly (configurable per sensor)
Data reception frequency	15 minutes or hourly
Time coverage	Covers the entire installation history of DLR sensor
Data format	JSON
Related test cases	TC1.4.2

Dataset DS.GR.08

Dataset ID	**DS.GR.08**

Data element	Environmental forecasts
Data description	High-resolution weather forecasts including ambient temperature, wind speed, wind direction, and solar radiation, used for conductor ampacity and thermal rating calculations in the RTTR tool
Confidentiality	Public (sourced from publicly available weather forecast services)
Access	Integrated into the RTTR tool via API; forecasts are automatically ingested and stored in the RTTR database
Source of data	Weather service providers or meteorological forecast APIs integrated with the RTTR tool
Measurement units	Temperature (°C), Wind speed (m/s), Wind direction (degrees), Solar radiation (W/m^2)
Resolution	Hourly
Data reception frequency	Hourly
Time coverage	Covers the entire duration of the demonstration activities
Data format	JSON
Related test cases	TC1.4.2

Dataset DS.GR.09

Dataset ID	**DS.GR.09**
Data element	Transformer historical monitoring data
Data description	Time-series dataset containing historical operational measurements from transformer assets. Includes key parameters such as oil temperature, ambient temperature, HV current, DGA gas levels, and bushing capacitance/tan delta. Used for anomaly detection, and health status estimation of transformers
Confidentiality	Confidential – includes potentially sensitive operational data from transformers managed by TSOs
Access	Uploaded manually by the user via the UI
Source of data	TSO users are responsible for collecting the necessary information using On-Line Monitoring Systems (OLMS)
Measurement units	Varies per measurement type: • Timestamp (dd/mm/yyyy hh:mm:ss) • °C (temperatures) Top oil & Ambient temperatures • A (Current) HV current • kV (Voltage) • ppm (gas concentrations) H_2, CH_4, C_2H_2, C_2H_6, C_2H_4 • pF (capacitance) • % (tandelta - HV1–HV3 / LV1–LV3)
Resolution	Minimum sampling period: 1 hour
Data reception frequency	Uploaded on demand by the user covering a defined historical period
Time coverage	A minimum period of four months is required
Data format	CSV (UTF-8 encoding), with required columns: Timestamp, Measurement, Value (detailed information for the format of the file is available in D5.4)
Related test cases	TC1.5.3

Dataset DS.GR.10

Dataset ID	DS.GR.10
Data element	Transformer monitoring data from OLMS
Data description	Time-series measurements collected by the On-Line Monitoring System (OLMS) installed on a transformer. The user should create in the SFTP server directory "transformer_olms_data" a dedicated folder - e.g. Asset 1 - where the OLMS data of that specific transformer are uploaded
Confidentiality	Confidential – includes sensitive operational data of critical grid assets
Access	Uploaded by the user to a predefined SFTP server
Source of data	Transformer On-Line Monitoring System (OLMS)
Measurement units	Minimum Information: • A (Current) • ˚C (Temperature)
Resolution	Minimum: 1-hour
Data reception frequency	Daily
Time coverage	Last day's data
Data format	CSV
Related test cases	TC1.5.3

Dataset DS.GR.11

Dataset ID	DS.GR.11
Data element	Load profile (power curves)
Data description	Represents hourly active power consumption data for each MV/LV substation in the examined network. This time-series data is used to evaluate scenarios under realistic demand profiles
Confidentiality	Confidential – contains sensitive load-profile data, corresponding to specific substations of a distribution grid
Access	Uploaded manually by the user via the planning tool UI
Source of data	DSO users are responsible for collecting the necessary information using the available internal sources
Measurement units	MW (active power per substation bus)
Resolution	1-hour
Data reception frequency	Provided as a complete annual dataset uploaded on demand by the user.
Time coverage	Represents one full calendar year
Data format	CSV (UTF-8 encoding). Each row corresponds to one hour of the year (0–8759), and each column (after the first) corresponds to a substation bus (detailed information for the format of the file is available in D5.4).
Related test cases	TC1.7.2, TC2.1.1

Dataset DS.GR.12

Dataset ID	DS.GR.12
Data element	Substation power factor data (cosφ)
Data description	Static information about the power factor (cosφ) at each MV/LV substation bus, used to determine reactive power characteristics and support power flow and optimization analysis
Confidentiality	Confidential – contains grid operation data that may reveal technical characteristics of specific substations.
Access	Uploaded manually by the user via the planning tool UI
Source of data	DSO users are responsible for collecting the necessary information using the available internal sources
Measurement units	Unitless (values between 0 and 1)
Resolution	N/A – static dataset
Data reception frequency	Uploaded on demand by the user
Time coverage	N/A – static representation of the power factor in the substations of a distribution grid
Data format	CSV (UTF-8 encoding). Each row in the data file includes the substation name and its corresponding power factor value (detailed information for the format of the file is available in D5.4).
Related test cases	TC1.7.2, TC2.1.1

Dataset DS.GR.13

Dataset ID	DS.GR.13
Data element	Information on the lines that will be considered for possible upgrade
Data description	Contains technical and economic specifications of line types that can be considered in grid upgrades. Each row corresponds to a specific line and includes electrical parameters (resistance, reactance, current capacity), line-type (overhead/underground), and upgrade cost. This information is used in the optimization analysis to evaluate upgrade strategies.
Confidentiality	Confidential – includes sensitive cost data and internal infrastructure parameters regarding specific lines within a distribution grid
Access	Uploaded manually by the user via the planning tool UI
Source of data	DSO users are responsible for collecting the necessary information using any available internal sources, such as utility records and technical specification documents
Measurement units	• Ohm/km (resistance/reactance) • kA (maximum current) • €/km (cost)
Resolution	N/A – static data
Data reception frequency	Uploaded on demand by the user
Time coverage	Applicable throughout the simulated planning horizon (e.g., next 15 years)
Data format	CSV (UTF-8 encoding). Each row in the file should include the following fields in the specified order (detailed information for the format of the file is available in D5.4):

	• Name (string) • r_ohm_per_km (float) • x_ohm_per_km (float) • max_i_ka (float) • cost_per_km_€ (float) • type (string)
Related test cases	TC1.7.2, TC2.1.1

Dataset DS.GR.14

Dataset ID	**DS.GR.14**
Data element	Distribution network topology
Data description	Static information for the distribution grid layout: buses, lines, substations, and generators. It includes parameters such as nominal voltages, line lengths, impedances, and substation coordinates. The data is essential for power flow and optimization analyses in the planning tool.
Confidentiality	Confidential – contains sensitive grid infrastructure data (e.g., exact substation locations, line parameters)
Access	Uploaded manually by the user via the planning tool UI
Source of data	DSO users should collect the necessary information using the available internal resources, such as GIS systems, SCADA databases, utility planning databases, or other relevant data repositories
Measurement units	Buses: • kV (nominal voltage) • MVA (of the transformer is substation exists) Lines: • km (length of the line) • ohm per km (Electrical resistance/reactance) • nano Farad per km (line capacitance (line-to-earth)) • micro Siemens per km (dielectric conductance) • kA (maximum current for the line) Generators: • MW (max power)
Resolution	N/A – static dataset
Data reception frequency	N/A – uploaded when needed by the user
Time coverage	N/A – static representation of network
Data format	JSON (pandapower format)
Related test cases	TC1.7.2, TC2.1.1

Dataset DS.GR.15

Dataset ID	**DS.GR.15**
Data element	Asset power consumption
Data description	Time series of power consumption from individual assets

Confidentiality	Confidential (contains data linked to occupants and potentially to their behaviour)
Access	Accessible via API from pilots' EMS to BFMS
Source of data	Assets at each pilot site
Measurement units	W
Resolution	15 min
Data reception frequency	15 min
Time coverage	September 2025 – end of project
Data format	JSON
Related test cases	TC1.2.4, TC1.8.1.1

Dataset DS.GR.16

Dataset ID	**DS.GR.16**
Data element	Asset baseline power consumption forecast
Data description	Time series of baseline power consumption forecast from individual assets
Confidentiality	Confidential (contains data linked to occupants and potentially to their behaviour)
Access	BFMS: Accessible via BFMS API, gathered per portfolio by FSPs provided by HYP NODES: Accessible via NODES, gathered per portfolio by FSPs provided by ICCS
Source of data	BFMS, aggregated smart meters data
Measurement units	W
Resolution	15 min
Data reception frequency	15 min
Time coverage	October 2025 – end of project
Data format	JSON
Related test cases	TC1.8.1.1, TC1.10.1

Dataset DS.GR.17

Dataset ID	**DS.GR.17**
Data element	Asset flexibility power consumption forecast
Data description	Time series of flexibility power consumption forecast from individual assets
Confidentiality	Confidential (contains data linked to occupants and potentially to their behaviour)
Access	Accessible via BFMS API
Source of data	BFMS
Measurement units	W
Resolution	15 min
Data reception frequency	15 min

Time coverage	October 2025 – end of project
Data format	JSON
Related test cases	TC1.8.2.1

Dataset DS.GR.18

Dataset ID	**DS.GR.18**
Data element	Control signals to assets at pilot sites
Data description	Time series of control signals to individual assets
Confidentiality	Confidential (contains data linked to occupants)
Access	Send directly to each asset (over the corresponding EMS/ Data Space)
Source of data	BFMS
Measurement units	N/A
Resolution	15 mins
Data reception frequency	15 mins
Time coverage	October 2025 – end of project
Data format	JSON
Related test cases	TC1.8.3.1

Dataset DS.GR.19

Dataset ID	**DS.GR.19**
Data element	Consumers' preferences per asset
Data description	Preferences of consumers per controllable asset, e.g., temperature range, timeframe of operation, etc.
Confidentiality	Confidential (contains data linked to occupants)
Access	Preferences accessed through the initial settings UI and the BFMS API
Source of data	EMS and initial settings UI
Measurement units	Various (depending on the declared preference)
Resolution	N/A
Data reception frequency	N/A
Time coverage	From first occurrence of preference setting until end of project
Data format	JSON
Related test cases	TC1.9.1

Dataset DS.GR.20

Dataset ID	**DS.GR.20**
Data element	Asset data
Data description	Asset characteristics covering type of assets, location, installed capacity

Confidentiality	Confidential
Access	NODES platform
Source of data	FSPs
Measurement units	N/A
Resolution	N/A
Data reception frequency	Once
Time coverage	N/A
Data format	CSV
Related test cases	TC1.10.1

10.2.2 Swiss pilot site datasets

Dataset DS.CH.01

Dataset ID	DS.CH.01
Data element	Baseline per portfolio
Data description	Confidential
Confidentiality	Confidential
Access	Accessible via NODES, provided by SUPSI
Source of data	BFMS
Measurement units	kW
Resolution	15 min
Data reception frequency	15 min
Time coverage	October 2025 – end of project
Data format	CSV
Related test cases	TC1.10.3

Dataset DS.CH.02

Dataset ID	DS.CH.02
Data element	Metering data/Smart meters
Data description	Net metering data in anonymised format associated to a specific ID
Confidentiality	Confidential
Access	REST API
Source of data	Landis+Gyr Advanced Metering Infrastructure (AMI)
Measurement units	Imported active power (W) Exported active power (W)
Resolution	15 minutes
Data reception frequency	6 hours on average
Time coverage	2019 - ongoing
Data format	CSV, JSON
Related test cases	TC1.1.2, TC1.3.2, TC1.6.1, TC1.10.3, TC5.1.1, TC5.2.1

Dataset DS.CH.03

Dataset ID	DS.CH.03
Data element	Grid infrastructure – high level information
Data description	Simplified replication of grid structure at the pilot location
Confidentiality	Confidential
Access	NODES platform
Source of data	System operator (AEM)
Measurement units	Grid nodes, grid node connections
Resolution	N/A – static

Data reception frequency	Once
Time coverage	N/A – static
Data format	GeoJSON
Related test cases	TC1.10.3

Dataset DS.CH.04

Dataset ID	**DS.CH.04**
Data element	Asset data
Data description	Asset characteristics covering type of assets, location, installed capacity
Confidentiality	Confidential
Access	NODES platform, HYP (HEMS), FSP (market script)
Source of data	FSPs (received from the pilot manager)
Measurement units	N/A – static
Resolution	N/A – static
Data reception frequency	Once (possibility of updates)
Time coverage	N/A – static
Data format	CSV
Related test cases	TC1.10.3, TC5.1.1, TC5.2.1

Dataset DS.CH.05

Dataset ID	**DS.CH.05**
Data element	Smart meter (single POD for NILM)
Data description	Net metering data in anonymised format associated to a specific ID
Confidentiality	Confidential (personal anonymised data)
Access	REST API
Source of data	Landis+Gyr Advanced Metering Infrastructure (AMI)
Measurement units	Imported active power (W) Exported active power (W)
Resolution	1 minute
Data reception frequency	Limited to historical data (no live data)
Time coverage	Training period: 1 month of historical data Testing period: 1 week
Data format	CSV, JSON, Excel
Related test cases	TC1.2.2

Dataset DS.CH.06

Dataset ID	**DS.CH.06**
Data element	Grid topology

Data description	The topology of the GIS in the area affected by the test (pilot site area)
Confidentiality	Confidential
Access	Project repository or email sharing
Source of data	Smart Grid Interface Module (SGIM)
Measurement units	Number of assets classified per category Technical specifications of assets
Resolution	N/A – static
Data reception frequency	Once
Time coverage	N/A – static
Data format	GeoJSON
Related test cases	TC1.6.1, TC1.3.2

Dataset DS.CH.07

Dataset ID	**DS.CH.07**
Data element	Weather data
Data description	Weather data of temperature, humidity, irradiation etc. from the Open weather data service
Confidentiality	Confidential
Access	Open weather API
Source of data	Open weather
Measurement units	Variable, depending on the TC requirements
Resolution	Minimum 1 hour
Data reception frequency	Minimum 1 hour
Time coverage	Minimum 1 hour
Data format	JSON, CSV or similar
Related test cases	TC1.1.2, TC1.3.2

Dataset DS.CH.08

Dataset ID	**DS.CH.08**
Data element	Indoor temperature and humidity
Data description	Data related to selected buildings with heat pumps and electric boilers
Confidentiality	Confidential
Access	REST API
Source of data	Shelly H&T
Measurement units	Humidity hum (%) Temperature temp (°C)
Resolution	15 minutes
Data reception frequency	Event based (Delta T)
Time coverage	From December 2025

Data format	CSV, JSON, Excel
Related test cases	TC5.1.1

Dataset DS.CH.09

Dataset ID	**DS.CH.09**
Data element	Grid meter
Data description	The SGIM device is installed in the distribution cabinet on the LV side of the MV/LV transformer at the secondary substation. The device is equipped with two groups of Rogowski coils, which allow for the measurement of two channels with a single device. Channel 1: LV side of the transformer Channel 2: Pilot site feeder
Confidentiality	Confidential (sensitive grid data)
Access	REST API
Source of data	Smart Grid Interface Module (SGIM)
Measurement units	• Active Power <channel>ActivePowL<phase> (kW) • Reactive Power <channel>ActivePowL<phase> (kW) • RMS Current <channel>CurrentL<phase> (A) • Voltage VoltageL<phase>N (V) • Power Factor <channel>PowFactorL<phase> <channel>: 1, 2 (some SGIM might have only channel 1 or channel 2 if only a measurement is needed) <phase>: 1, 2, 3
Resolution	1 minute
Data reception frequency	Real-time
Time coverage	30/01/2024 – Ongoing
Data format	CSV, JSON, Excel
Related test cases	TC1.1.2, TC1.3.2, TC1.6.1, TC5.1.1, TC5.2.1

Dataset DS.CH.10

Dataset ID	**DS.CH.10**
Data element	Consumers' preferences per asset
Data description	Preferences of consumers per controllable asset, e.g., temperature range, timeframe of operation, etc.
Confidentiality	Confidential (contains data linked to occupants)
Access	Preferences accessed through the initial settings UI and the BFMS API
Source of data	EMS and initial settings UI
Measurement units	Various (depending on the declared preference)
Resolution	N/A
Data reception frequency	N/A
Time coverage	From first occurrence of preference setting until end of project
Data format	JSON

Related test cases	TC1.9.2

Dataset DS.CH.11

Dataset ID	**DS.CH.11**
Data element	Control signals to assets at pilot sites
Data description	Time series of control signals to individual assets
Confidentiality	Confidential (contains data linked to occupants)
Access	Send directly to each asset (over the corresponding EMS/ Data Space)
Source of data	BFMS
Measurement units	N/A
Resolution	15 min
Data reception frequency	15 min
Time coverage	October 2025 – end of project
Data format	JSON
Related test cases	TC1.8.3.3

Dataset DS.CH.12

Dataset ID	**DS.CH.12**
Data element	Asset flexibility power consumption forecast
Data description	Time series of flexibility power consumption forecast from individual assets
Confidentiality	Confidential (contains data linked to occupants and potentially to their behaviour)
Access	Accessible via BFMS API
Source of data	BFMS
Measurement units	W
Resolution	15 min
Data reception frequency	15 min
Time coverage	October 2025 – end of project
Data format	JSON
Related test cases	TC1.8.2.3

Dataset DS.CH.13

Dataset ID	**DS.CH.13**
Data element	Asset power consumption
Data description	Time series of power consumption from individual assets
Confidentiality	Confidential (contains data linked to occupants and potentially to their behaviour)
Access	Accessible via API from pilots' EMS to BFMS

Source of data	Assets at each pilot site
Measurement units	W
Resolution	15 min
Data reception frequency	15 min
Time coverage	September 2025 – end of project
Data format	JSON
Related test cases	TC1.8.1.3

Dataset DS.CH.14

Dataset ID	**DS.CH.14**
Data element	Asset baseline power consumption forecast
Data description	Time series of baseline power consumption forecast from individual assets
Confidentiality	Confidential (contains data linked to occupants and potentially to their behaviour)
Access	Accessible via BFMS API
Source of data	BFMS
Measurement units	W
Resolution	15 min
Data reception frequency	15 min
Time coverage	October 2025 – end of project
Data format	JSON
Related test cases	TC1.8.1.3

10.2.3 Spanish pilot site datasets

Dataset DS.SP.01

Dataset ID	DS.SP.01
Data element	Smart meter and submetering data
Data description	Time series of active/reactive power for smart meters and active power for submetering. Used to train and validate NILM disaggregation models.
Confidentiality	Confidential – may contain data tied to user behaviour
Access	Accessible via API from Shelly Cloud platform and SFTP, depending on the user. Data being stored in ETRA influxdb database.
Source of data	Shelly devices and smart meters
Measurement units	kW, kVAr
Resolution	Close to real time for Shelly devices and 15 minutes for SFTP metering curves
Data reception frequency	Real-time stream for Shelly devices and daily for SFTP metering curves
Time coverage	June 2025 - ongoing
Data format	JSON
Related test cases	TC1.2.1, TC1.10.2

Dataset DS.SP.02

Dataset ID	DS.SP.02
Data element	Voltage variation data in Spanish pilot
Data description	Time series of voltage deviation from nominal (P.U.) voltage by grid element
Confidentiality	Confidential
Access	Data being stored in ETRA influxdb database
Source of data	Test cycles and state estimation calculation module
Measurement units	%
Resolution	60 minutes
Data reception frequency	60 minutes
Time coverage	August 2025 - ongoing
Data format	JSON
Related test cases	TC1.2.4

Dataset DS.SP.03

Dataset ID	DS.SP.03
Data element	Electrical grid estimated measurements in Spanish pilot
Data description	Time series of electrical grid measurements
Confidentiality	Confidential

Access	Data being stored in ETRA influxdb database
Source of data	State estimation calculation module
Measurement units	kW, kVar, A, and V
Resolution	60 minutes
Data reception frequency	60 minutes
Time coverage	August 2025 - ongoing
Data format	JSON
Related test cases	TC1.1.1, TC1.3.3

Dataset DS.SP.04

Dataset ID	**DS.SP.04**
Data element	Alerts inserted in lines with suspicious activity
Data description	Alerts inserted in lines with suspicious activity, with datetime of the source data used as input for the NTL computation process
Confidentiality	Non confidential
Access	Displayed in ETER platform >> in portfolio section >> line subsection, with visual alert, and in line highlighted in map if there are non-fixed NTL alerts in database
Source of data	Smart meters, submeters and feeders' data. State estimation and powerflow results
Measurement units	Boolean: suspicious/nonsuspicious
Resolution	Same as forecast
Data reception frequency	15 minutes
Time coverage	July 2025 - ongoing
Data format	JSON
Related test cases	TC1.3.3

Dataset DS.SP.05

Dataset ID	**DS.SP.05**
Data element	Real-time operational data from DSO's SCADA
Data description	Real-time operational data provided from DSO's SCADA
Confidentiality	Confidential – includes live operational measurements from distribution infrastructure, potentially sensitive to grid operator.
Access	Data from the SCADA of the DSO are sent automatically to the RTTR tool through MQTT messages, where they are received in real time and stored directly in the RTTR database for processing and analysis.
Source of data	DSO provides data infrastructure real-time sensor feed installed on line-segments
Measurement units	Line current (Amperes)
Resolution	1 minute
Data reception frequency	Real-time
Time coverage	Covers the entire duration of the demonstration activities

Data format	JSON
Related test cases	TC1.4.1

Dataset DS.SP.06

Dataset ID	**DS.SP.06**
Data element	Topological data of the lines
Data description	Topological information that defines the physical and electrical characteristics of each line section of the lines processed by the tool
Confidentiality	Confidential – includes detailed information for distribution infrastructure, which is sensitive for the grid operation
Access	Data from the DSO, uploaded by the user via the UI for the RTTR module
Source of data	DSO users are responsible for collecting the necessary information using the available internal sources
Measurement units	• Latitude and longitude in decimal degrees (EPSG:4326 standard) • mm (cross section) • Ω/km (electrical resistance/reactance) • A (maximum admissible current) • m (line length)
Resolution	N/A – static data
Data reception frequency	Uploaded on demand by the user – can be updated in case of reconfiguration of the examined line(s)
Time coverage	Static data (covers the current structure of the examined grid)
Data format	CSV (UTF-8 encoding). Each row in the file represents a single section of the line, with the following required fields in the specified order: • line_section_name (string) • overhead_or_underground (string). • cross_section_sq_mm (float) • resistance_ohm_km (float) • reactance_ohm_km (float) • current_admissable_A (float) • line_length_m (float) • lat_start / lon_start / lat_end / lon_end (float) Detailed information for the format of the file is available in D5.4
Related test cases	TC1.4.1

Dataset DS.SP.07

Dataset ID	**DS.SP.07**
Data element	Historical current measurements
Data description	Historical measurement data that are used for the training of forecasting models and enriching the analysis. They include current measurements, average or per phase from any other source (e.g. SCADA) that are used for model training, analysis, and visualization within the tool.
Confidentiality	Confidential – includes sensitive information for grid assets

Access	Data from the DSO. Uploaded manually by the user via the UI for the RTTR module.
Source of data	DSO users are responsible for collecting the necessary information using the available internal sources, such as SCADA system or PMUs
Measurement units	Amperes (A)
Resolution	Minimum: 1 hour
Data reception frequency	Uploaded on demand by the user
Time coverage	Static data
Data format	CSV (UTF-8 encoding), that includes the following three columns, in the specified order: • Timestamp in the format dd/mm/yyyy hh:mm:ss, in local time. • Measurement (string) • Value (float) Detailed information for the format of the file is available in D5.4
Related test cases	TC1.4.1

Dataset DS.SP.08

Dataset ID	**DS.SP.08**
Data element	Real-time operational data from dynamic line rating (DLR) sensors
Data description	Real-time operational data from Dynamic Line Rating (DLR) sensors.
Confidentiality	Confidential – includes live operational measurements from distribution infrastructure, potentially sensitive to grid operator.
Access	Uploaded automatically to RTTR's database through an API. Authorised User can access the data through the RTTR UI interface.
Source of data	DSO provides data infrastructure real-time sensor feed installed on line-segments
Measurement units	• Conductor temperature (°C) • Ambient temperature (°C) • Wind speed & direction (m/s, degrees) • Line current (Amperes) • Relative humidity (%) • Mechanical tension (kN)
Resolution	15 minutes or hourly (configurable per sensor)
Data reception frequency	15 minutes or hourly
Time coverage	Covers the entire installation history of DLR sensor
Data format	JSON
Related test cases	TC1.4.1

Dataset DS.SP.09

Dataset ID	**DS.SP.09**
Data element	Environmental forecasts
Data description	High-resolution weather forecasts including ambient temperature, wind speed, wind direction, and solar radiation, used for conductor ampacity and thermal rating calculations in the RTTR tool.

Confidentiality	Public (sourced from publicly available weather forecast services)
Access	Integrated into the RTTR tool via API; forecasts are automatically ingested and stored in the RTTR database.
Source of data	Weather service providers or meteorological forecast APIs integrated with the RTTR tool
Measurement units	• Temperature (°C) • Wind speed (m/s) • Wind direction (degrees) • Solar radiation (W/m²)
Resolution	hourly
Data reception frequency	hourly
Time coverage	Covers the entire duration of the demonstration activities
Data format	JSON
Related test cases	TC1.4.1

Dataset DS.SP.10

Dataset ID	**DS.SP.10**
Data element	Smart meter historical data
Data description	Historical data about the smart meters including information about the metering point, the secondary substation that it belongs to, the installation date, the brand and the model, etc.
Confidentiality	Confidential – the file potentially includes asset-specific identifiers and geolocation information that can be linked to customer infrastructure or utility grid topology.
Access	Uploaded manually by the user via the UI for the long-term asset management module.
Source of data	DSO users are responsible for collecting the necessary information using any available internal sources, such as smart metering infrastructure (AMI), customer information systems (CIS) or asset registries.
Measurement units	N/A – static data (e.g., strings, dates, integers).
Resolution	N/A – static data
Data reception frequency	Uploaded on demand by the user.
Time coverage	Covers the entire installation history of smart meters
Data format	CSV (UTF-8 encoding), with columns: • smart_meter_id (integer) • delivery_point_id (integer) • model (string) • installation_date (dd/mm/yyyy hh:mm:ss) Optional columns: • secondary_substation (string) • feeder_nb (integer) Detailed information for the format of the file is available in D5.4
Related test cases	TC1.5.4

Dataset DS.SP.11

Dataset ID	DS.SP.11
Data element	Geodata of the secondary substations
Data description	Contains the geographic coordinates (latitude, longitude) and identifiers of secondary substations linked to smart meters. This file enables spatial planning and resource allocation, supporting a visual distribution of critical meters by substation, along with a map-based representation for geographic context. Operators can quickly pinpoint vulnerable areas in the grid and coordinate field responses efficiently.
Confidentiality	Confidential – includes sensitive infrastructure data, such as detailed geographic locations of substations.
Access	Uploaded manually by the user via the UI for the long-term asset management module.
Source of data	DSO users are responsible for collecting the necessary information using any available internal sources, such as GIS systems, grid registries.
Measurement units	Latitude and Longitude in decimal degrees (EPSG:4326 standard)
Resolution	N/A – static data
Data reception frequency	Uploaded on demand by the user (updated if the substation topology changes)
Time coverage	Static data (covers the current structure of the examined grid)
Data format	CSV (UTF-8 encoding), with columns: • ID (string) • NAME (string) • LAT (float) • LON (float)
Related test cases	TC1.5.4

Dataset DS.SP.12

Dataset ID	DS.SP.12
Data element	Smart meter SFTP data
Data description	Information required for training the machine learning models that predict failure probabilities of smart meters.
Confidentiality	Confidential – includes sensitive users' data
Access	Uploaded automatically by the user to a predefined SFTP server
Source of data	DSO users are responsible for collecting the necessary information from AMI and sending them to the SFTP server.
Measurement units	• kWh • kVarh
Resolution	Minimum: 1 hour
Data reception frequency	Daily
Time coverage	Last day's data
Data format	CSV
Related test cases	TC1.5.4

Dataset DS.SP.13

Dataset ID	DS.SP.13
Data element	Load profile (power curves)
Data description	Represents hourly active power consumption data for each MV/LV substation in the examined network. This time-series data is used to evaluate scenarios under realistic demand profiles.
Confidentiality	Confidential – contains sensitive load-profile data, corresponding to specific substations of a distribution grid.
Access	Uploaded manually by the user via the planning tool UI
Source of data	DSO users are responsible for collecting the necessary information using the available internal sources.
Measurement units	MW (active power per substation bus)
Resolution	1 hour
Data reception frequency	Provided as a complete annual dataset uploaded on demand by the user.
Time coverage	Represents one full calendar year.
Data format	CSV (UTF-8 encoding). Each row corresponds to one hour of the year (0–8759), and each column (after the first) corresponds to a substation bus (detailed information for the format of the file is available in D5.4).
Related test cases	TC4.5.1

Dataset DS.SP.14

Dataset ID	DS.SP.14
Data element	Substation power factor data (cosφ)
Data description	Static information about the power factor (cosφ) at each MV/LV substation bus, used to determine reactive power characteristics and support power flow and optimization analysis.
Confidentiality	Confidential – contains grid operation data that may reveal technical characteristics of specific substations.
Access	Uploaded manually by the user via the planning tool UI
Source of data	DSO users are responsible for collecting the necessary information using the available internal sources.
Measurement units	Unitless (values between 0 and 1)
Resolution	N/A – static dataset
Data reception frequency	Uploaded on demand by the user.
Time coverage	Static representation of the power factor in the substations of a distribution grid
Data format	CSV (UTF-8 encoding). Each row in the data file includes the substation name and its corresponding power factor value (detailed information for the format of the file is available in D5.4).
Related test cases	TC4.5.1

Dataset DS.SP.15

Dataset ID	DS.SP.15

Data element	Information on the lines that will be considered for possible upgrade
Data description	Contains technical and economic specifications of line types that can be considered in grid upgrades. Each row corresponds to a specific line and includes electrical parameters (resistance, reactance, current capacity), line-type (overhead/underground), and upgrade cost. This information is used in the optimization analysis to evaluate upgrade strategies.
Confidentiality	Confidential – includes sensitive cost data and internal infrastructure parameters regarding specific lines within a distribution grid.
Access	Uploaded manually by the user via the planning tool UI
Source of data	DSO users are responsible for collecting the necessary information using any available internal sources, such as utility records and technical specification documents.
Measurement units	• Ohm/km (resistance/reactance) • kA (maximum current) • €/km (cost)
Resolution	N/A – static data
Data reception frequency	Uploaded on demand by the user.
Time coverage	Applicable throughout the simulated planning horizon (e.g., next 15 years).
Data format	CSV (UTF-8 encoding). Each row in the file should include the following fields in the specified order (detailed information for the format of the file is available in D5.4): • Name (string) • r_ohm_per_km (float) • x_ohm_per_km (float) • max_i_ka (float) • cost_per_km_€: (float) • type (string)
Related test cases	TC4.5.1

Dataset DS.SP.16

Dataset ID	**DS.SP.16**
Data element	Distribution network topology
Data description	Static information for the distribution grid layout: buses, lines, substations, and generators. It includes parameters such as nominal voltages, line lengths, impedances, and substation coordinates. The data is essential for power flow and optimization analyses in the planning tool.
Confidentiality	Confidential – contains sensitive grid infrastructure data (e.g., exact substation locations, line parameters).
Access	Uploaded manually by the user via the planning tool UI
Source of data	DSO users should collect the necessary information using the available internal resources, such as GIS systems, SCADA databases, utility planning databases, or other relevant data repositories.
Measurement units	Buses: • kV (nominal voltage)

	• MVA (of the transformer is substation exists) Lines: • km (length of the line) • ohm per km (Electrical resistance/reactance) • nano Farad per km (line capacitance (line-to-earth)) • micro Siemens per km (dielectric conductance) • kA (maximum current for the line) Generators: • MW (max power)
Resolution	N/A - static dataset
Data reception frequency	N/A: Uploaded when needed by the user.
Time coverage	Static representation of network
Data format	Excel (.xlsx). The file includes the following information (detailed information for the format of the file is available in D5.4): • Buses: name (string), vn_kv (float), substation (Boolean), latitude (float), longitude (float), sn_mva (float) • Lines: name (string), from_bus (string), to_bus (string), length_km (float), r_ohm_per_km (float), x_ohm_per_km (float), c_nf_per_km (float), g_us_per_km (float), max_i_ka (float), type (string), • Substations: Column bus (string) • Generators (if any): bus (string), name (string), p_max_mw (float)
Related test cases	TC1.1.1, TC1.3.3, TC1.4.1, TC1.5.4, TC4.1.1, TC4.2.1, TC4.3.1, TC4.4.1, TC4.5.1

Dataset DS.SP.17

Dataset ID	**DS.SP.17**
Data element	Asset power consumption
Data description	Time series of power consumption from individual assets
Confidentiality	Confidential (contains data linked to occupants and potentially to their behavior)
Access	Accessible via API from pilots' EMS to BFMS
Source of data	Assets at each pilot site
Measurement units	W
Resolution	15 min
Data reception frequency	15 min
Time coverage	September 2025 – end of project
Data format	JSON
Related test cases	TC1.8.1.2

Dataset DS.SP.18

Dataset ID	**DS.SP.18**
Data element	Asset baseline power consumption forecast
Data description	Time series of baseline power consumption forecast from individual assets

Confidentiality	Confidential (contains data linked to occupants and potentially to their behavior)
Access	Accessible via BFMS API
Source of data	BFMS
Measurement units	W
Resolution	15 minutes
Data reception frequency	15 minutes
Time coverage	October 2025 – end of project
Data format	JSON
Related test cases	T1.8.1.2, TC1.10.2

Dataset DS.SP.19

Dataset ID	**DS.SP.19**
Data element	Asset flexibility power consumption forecast
Data description	Time series of flexibility power consumption forecast from individual assets
Confidentiality	Confidential (contains data linked to occupants and potentially to their behavior)
Access	Accessible via BFMS API
Source of data	BFMS
Measurement units	W
Resolution	15 minutes
Data reception frequency	15 minutes
Time coverage	October 2025 – end of project
Data format	JSON
Related test cases	TC1.8.2.2

Dataset DS.SP.20

Dataset ID	**DS.SP.20**
Data element	Dispatch of control signals to assets at pilot sites
Data description	Time series of control signals to individual assets
Confidentiality	Confidential (contains data linked to occupants)
Access	Send directly to each asset (over the corresponding EMS/ Data Space)
Source of data	BFMS
Measurement units	N/A
Resolution	15 minutes
Data reception frequency	15 minutes
Time coverage	October 2025 – end of project
Data format	JSON
Related test cases	T1.8.3.2

Dataset DS.SP.21

Dataset ID	DS.SP.21
Data element	Power curves, including voltages at delivering points
Data description	Power curves (P,Q, V, I) of the required smart meters with 15 mins granularity (1 year)
Confidentiality	Confidential – may contain data tied to user behaviour
Access	Accessible via MQTT platform and historical files. Data being stored in ETRA influxdb database
Source of data	SCADA system and state estimation results
Measurement units	kW, kVAr
Resolution	15 minutes
Data reception frequency	Periodic
Time coverage	1 year
Data format	JSON
Related test cases	TC4.1.1

Dataset DS.SP.22

Dataset ID	DS.SP.22
Data element	Grid topology in the considered period
Data description	Status of the topology in the analysed period (for comparison), adjacency matrix
Confidentiality	Confidential – may contain data tied to user behaviour
Access	Offline access
Source of data	Topology access file
Measurement units	N/A
Resolution	N/A
Data reception frequency	Offline access
Time coverage	N/A
Data format	CSV
Related test cases	TC4.1.1

Dataset DS.SP.23

Dataset ID	DS.SP.23
Data element	Grid infrastructure – high level information
Data description	Simplified replication of grid structure at the pilot location
Confidentiality	Confidential
Access	NODES platform
Source of data	System Operators (HEDNO/IPTO)
Measurement units	Grid nodes, grid node connections

Resolution	N/A
Data reception frequency	Once
Time coverage	N/A
Data format	GeoJSON
Related test cases	TC1.10.2

Dataset DS.SP.24

Dataset ID	**DS.SP.24**
Data element	Asset data
Data description	Asset characteristics covering type of assets, location, installed capacity
Confidentiality	Confidential
Access	NODES platform
Source of data	FSPs
Measurement units	N/A
Resolution	N/A
Data reception frequency	Once
Time coverage	N/A
Data format	CSV
Related test cases	TC1.10.2

10.2.4 Slovenian pilot site datasets

Dataset DS.SI.01

Dataset ID	DS.SI.01
Data element	EV charging power
Data description	Real and historical EV charging power measurements collected from AVANTCAR's fleet, grouped by charging station and location. Used for training forecast models, estimating flexibility, monitoring data availability, and validating optimized charging strategies.
Confidentiality	Confidential – includes potentially sensitive end-user or infrastructure data
Access	Accessed via AVANTCAR-provided API; authentication required
Source of data	AVANTCAR backend system (EV charging stations)
Measurement units	kW
Resolution	1 minute
Data reception frequency	1 minute
Time coverage	December 2023-June 2025
Data format	JSON
Related test cases	TC3.1.1, TC3.1.2, TC3.1.3, TC3.3.1, TC3.3.2, TC3.3.3

Dataset DS.SI.02

Dataset ID	DS.SI.02
Data element	HEMS power data per channel
Data description	Asset-level power measurements from Reduxi HEMS devices, including PV production, heat pump usage, EV charging, and grid interaction. Used for forecasting, flexibility estimation, reliability monitoring, and tariff optimization.
Confidentiality	Confidential – contains personal energy usage data
Access	Accessed via Amibit backend API (Reduxi platform); credentials required
Source of data	Reduxi HEMS device (Amibit platform)
Measurement units	kW
Resolution	1 minute
Data reception frequency	1 minute
Time coverage	March 2024-June 2025
Data format	JSON
Related test cases	TC3.2.1, TC3.2.2, TC3.2.3, TC3.3.1, TC3.3.4

Dataset DS.SI.03

Dataset ID	DS.SI.03
Data element	Market price forecasts
Data description	Forecasted electricity prices for Day-ahead and TSO flexibility markets. Used for optimizing EV charging schedules and evaluating market selection strategies.

Confidentiality	Confidential – generated using internal forecasting models or market tools
Access	Internal to SETUP platform; not externally distributed
Source of data	SETUP forecasting module
Measurement units	€/MWh
Resolution	Hourly
Data reception frequency	Generated once per day for the following day
Time coverage	1 day
Data format	JSON
Related test cases	TC3.3.2, TC3.3.3

Dataset DS.SI.04

Dataset ID	**DS.SI.04**
Data element	EV charging station metadata
Data description	Static metadata about EV charging stations, including measuring point ID, max charging power, current type (AC/DC), amperage, and location grouping. Used in forecasting and flexibility estimation.
Confidentiality	Confidential – includes infrastructure characteristics
Access	Accessed via AVANTCAR backend API
Source of data	AVANTCAR backend system
Measurement units	• kW • A • Categorical
Resolution	N/A - static
Data reception frequency	Static, updated only when configuration changes
Time coverage	Valid throughout the test period
Data format	CSV
Related test cases	TC3.1.1, TC3.1.2, TC3.1.3, TC3.3.2, TC3.3.3

Dataset DS.SI.05

Dataset ID	**DS.SI.05**
Data element	HEMS channel metadata
Data description	Static configuration metadata for Reduxi HEMS channels, including HEMS unit ID, category (device type), rated power, and optional user input on specific models. Used in forecast and flexibility models.
Confidentiality	Confidential – may include user-specified information
Access	Accessed via Amibit backend API
Source of data	Amibit backend system (Reduxi)
Measurement units	• Categorical • kW (for power limits)
Resolution	N/A - static
Data reception frequency	Static, updated by user or admin if needed

Time coverage	Valid for throughout the test period
Data format	CSV
Related test cases	TC3.2.1, TC3.2.2, TC3.2.3, TC3.3.4

Dataset DS.SI.06

Dataset ID	**DS.SI.06**
Data element	Flexibility bid scenarios
Data description	Synthetic flexibility requests (bids) used in simulations of the optimal selection algorithm. Each bid includes requested power, duration, and time window. Designed to test algorithm behaviour across varying constraints.
Confidentiality	Public – does not contain sensitive information
Access	Internally generated within UL test environment
Source of data	Defined manually or based on an algorithm as test input
Measurement units	• kW • minutes
Resolution	15-minute
Data reception frequency	Once per scenario
Time coverage	N/A - synthetic scenarios
Data format	JSON
Related test cases	TC3.3.1

Dataset DS.SI.07

Dataset ID	**DS.SI.07**
Data element	Asset constraints and parameters
Data description	Per-asset configuration including max flexibility, activation duration limits, resting periods, reliability scores, and cost coefficients. Used as constraints in the optimal selection algorithm. Also SoC and other parameters
Confidentiality	Public – does not contain sensitive information
Access	Internal simulation config file or static DB export
Source of data	Aggregated asset metadata from AVANTCAR and Amibit as well as simulation assumptions
Measurement units	• kW • minutes • € • %
Resolution	N/A - static per asset
Data reception frequency	N/A - static per scenario
Time coverage	Valid throughout the test period
Data format	JSON
Related test cases	TC3.3.1

Dataset DS.SI.08

Dataset ID	DS.SI.08
Data element	Tariff structure
Data description	Slovenian residential tariff structure including pricing blocks, peak/off-peak hours, and peak power penalty thresholds. Used to evaluate Reduxi HEMS cost optimization.
Confidentiality	Public – based on national tariff rules
Access	Manual import from official tariff documentation
Source of data	Slovenian national tariff documentation
Measurement units	• €/kWh • €/kW (penalties)
Resolution	Time-of-use blocks
Data reception frequency	N/A - static
Time coverage	Valid throughout the test period unless changed by regulator
Data format	CSV
Related test cases	TC3.3.4

Dataset DS.SI.09

Dataset ID	DS.SI.09
Data element	Smart meter historical data
Data description	Historical data about the smart meters, including information about the metering point, the secondary substation that it belongs to, the installation date, the brand and the model, etc.
Confidentiality	Confidential – the file potentially includes asset-specific identifiers and geolocation information that can be linked to customer infrastructure or utility grid topology
Access	Uploaded manually by the user via the UI for the long-term asset management module
Source of data	DSO users are responsible for collecting the necessary information using any available internal sources, such as smart metering infrastructure (AMI), customer information systems (CIS) or asset registries
Measurement units	N/A – strings, dates, integer values
Resolution	N/A – static data
Data reception frequency	Uploaded on demand by the user
Time coverage	Covers the entire installation history of smart meters
Data format	CSV (UTF-8 encoding), with columns. Detailed information for the format of the file is available in D5.4
Related test cases	TC1.5.1

Dataset DS.SI.10

Dataset ID	DS.SI.10
Data element	Geodata of the secondary substations
Data description	Contains the geographic coordinates (latitude, longitude) and identifiers of secondary substations linked to smart meters. This file enables spatial planning and resource allocation, supporting a

	visual distribution of critical meters by substation, along with a map-based representation for geographic context. Operators can quickly pinpoint vulnerable areas in the grid and coordinate field responses efficiently.
Confidentiality	Confidential – includes sensitive infrastructure data, such as detailed geographic locations of substations
Access	Uploaded manually by the user via the UI for the long-term asset management module
Source of data	DSO users are responsible for collecting the necessary information using any available internal sources, such as GIS systems, grid registries
Measurement units	Latitude and longitude in decimal degrees (EPSG:4326 standard)
Resolution	N/A – static data
Data reception frequency	Uploaded on demand by the user (updated if the substation topology changes)
Time coverage	N/A – static data (covers the current structure of the examined grid)
Data format	CSV (UTF-8 encoding), with columns: • ID (string) • NAME (string) • LAT (float) • LON (float)
Related test cases	TC1.5.1

Dataset DS.SI.11

Dataset ID	**DS.SI.11**
Data element	Smart meter SFTP data
Data description	Information required for training the machine learning models that predict failure probabilities of smart meters
Confidentiality	Confidential – includes sensitive users' data
Access	Uploaded automatically by the user to a predefined SFTP server
Source of data	DSO users are responsible for collecting the necessary information from AMI and sending them to the SFTP server
Measurement units	• kWh • kVarh
Resolution	Minimum: 1 hour
Data reception frequency	Daily
Time coverage	Last day's data
Data format	CSV
Related test cases	TC1.5.1

Dataset DS.SI.12

Dataset ID	**DS.SI.12**
Data element	Transformer historical monitoring data
Data description	Time-series dataset containing historical operational measurements from transformer assets. Includes key parameters

	such as oil temperature, ambient temperature, HV current. Used for anomaly detection, and health status estimation of transformers.
Confidentiality	Confidential – includes potentially sensitive operational data from transformers managed by DSOs
Access	Uploaded manually by the user via the UI
Source of data	DSO users are responsible for collecting the necessary information using On-Line Monitoring Systems (OLMS)
Measurement units	• Timestamp (in the format dd/mm/yyyy hh:mm:ss) • °C (temperature) Top oil & Ambient temperature • A (current) HV current
Resolution	Minimum: 1 hour
Data reception frequency	Uploaded on demand by the user covering a defined historical period.
Time coverage	Minimum: 4 months
Data format	CSV (UTF-8 encoding), with required columns: Timestamp, Measurement, Value (detailed information for the format of the file is available in D5.4)
Related test cases	TC1.5.2

Dataset DS.SI.13

Dataset ID	**DS.SI.13**
Data element	Transformer Monitoring Data from OLMS
Data description	Time-series measurements collected by the On-Line Monitoring System (OLMS) installed on a transformer. The user should create in the SFTP server directory “transformer_olms_data” a dedicated folder - e.g. Asset 1 - where the OLMS data of that specific transformer are uploaded.
Confidentiality	Confidential – includes sensitive operational data of critical grid assets
Access	Uploaded by the user to a predefined SFTP server
Source of data	Transformer On-Line Monitoring System (OLMS)
Measurement units	• A (current) • °C (temperature)
Resolution	Minimum: 1-hour
Data reception frequency	Daily
Time coverage	Previous day’s data
Data format	CSV file
Related test cases	TC1.5.2

Dataset DS.SI.14

Dataset ID	**DS.SI.14**
Data element	Load profile (power curves)
Data description	Represents hourly active power consumption data for each MV/LV substation in the examined network. This time-series data is used to evaluate scenarios under realistic demand profiles.

Confidentiality	Confidential – contains sensitive load-profile data, corresponding to specific substations of a distribution grid
Access	Uploaded manually by the user via the planning tool UI
Source of data	DSO users are responsible for collecting the necessary information using the available internal sources
Measurement units	MW (active power per substation bus)
Resolution	1-hour
Data reception frequency	Uploaded on demand by the user
Time coverage	Represents one full calendar year
Data format	CSV (UTF-8 encoding). Each row corresponds to one hour of the year (0–8759), and each column (after the first) corresponds to a substation bus (detailed information for the format of the file is available in D5.4).
Related test cases	TC1.7.1

Dataset DS.SI.15

Dataset ID	**DS.SI.15**
Data element	Substation power factor data (cosφ)
Data description	Static information about the power factor (cosφ) at each MV/LV substation bus, used to determine reactive power characteristics and support power flow and optimization analysis.
Confidentiality	Confidential – contains grid operation data that may reveal technical characteristics of specific substations
Access	Uploaded manually by the user via the planning tool UI
Source of data	DSO users are responsible for collecting the necessary information using the available internal sources
Measurement units	Unitless (values between 0 and 1)
Resolution	N/A – static dataset
Data reception frequency	Uploaded on demand by the user
Time coverage	Static representation of the power factor in the substations of a distribution grid
Data format	CSV (UTF-8 encoding). Each row in the data file includes the substation name and its corresponding power factor value (detailed information for the format of the file is available in D5.4).
Related test cases	TC1.7.1

Dataset DS.SI.16

Dataset ID	**DS.SI.16**
Data element	Information on the lines that will be considered for possible upgrade
Data description	Contains technical and economic specifications of line types that can be considered in grid upgrades. Each row corresponds to a specific line and includes electrical parameters (resistance, reactance, current capacity), line-type (overhead/underground), and upgrade cost. This information is used in the optimization analysis to evaluate upgrade strategies.

Confidentiality	Confidential – includes sensitive cost data and internal infrastructure parameters regarding specific lines within a distribution grid
Access	Uploaded manually by the user via the planning tool UI
Source of data	DSO users are responsible for collecting the necessary information using any available internal sources, such as utility records and technical specification documents
Measurement units	• Ohm/km (resistance/reactance) • kA (maximum current) • €/km (cost)
Resolution	N/A – static data
Data reception frequency	Uploaded on demand by the user.
Time coverage	Applicable throughout the simulated planning horizon (e.g., next 15 years)
Data format	CSV (UTF-8 encoding). Each row in the file should include the following fields in the specified order (detailed information for the format of the file is available in D5.4)
Related test cases	TC1.7.1

Dataset DS.SI.17

Dataset ID	**DS.SI.17**
Data element	Distribution network topology
Data description	Static information for the distribution grid layout: buses, lines, substations, and generators. It includes parameters such as nominal voltages, line lengths, impedances, and substation coordinates. The data is essential for power flow and optimization analyses in the planning tool.
Confidentiality	Confidential – contains sensitive grid infrastructure data (e.g., exact substation locations, line parameters)
Access	Uploaded manually by the user via the planning tool UI
Source of data	DSO users should collect the necessary information using the available internal resources, such as GIS systems, SCADA databases, utility planning databases, or other relevant data repositories.
Measurement units	Buses: • kV (nominal voltage) • MVA (of the transformer is substation exists) Lines: • km (length of the line) • ohm per km (Electrical resistance/reactance) • nano Farad per km (line capacitance (line-to-earth)) • micro Siemens per km (dielectric conductance) • kA (maximum current for the line) Generators: • MW (max power)
Resolution	N/A - static dataset
Data reception frequency	N/A – uploaded when needed by the user
Time coverage	Static representation of network
Data format	• EP: Excel (.xlsx) (detailed information for the format of the file is

	available in D5.4) • EL: CIM (v16)
Related test cases	TC1.7.1

Dataset DS.SI.18

Dataset ID	**DS.SI.18**
Data element	Smart meter and submetering data
Data description	Time series of active/reactive power for smart meters and active power for submetering. Used to train and validate NILM disaggregation models.
Confidentiality	Confidential – may contain data tied to user behaviour
Access	Accessible via MQTT from Reduxi devices, data being stored in ETRA influxDB database through rabbitMQ
Source of data	Smart meters and submeters
Measurement units	• kW • kVAr
Resolution	15 minutes
Data reception frequency	Real-time stream
Time coverage	July 2025 - ongoing
Data format	JSON
Related test cases	TC1.2.3, TC1.6.2

Dataset DS.SI.19

Dataset ID	**DS.SI.19**
Data element	Electrical grid estimated measurements in Slovenian pilot
Data description	Time series of electrical grid measurements
Confidentiality	Confidential
Access	Data being stored in ETRA influxDB database.
Source of data	State estimation calculation module
Measurement units	• kW • kVar • A • V
Resolution	1 hour
Data reception frequency	1 hour
Time coverage	August 2025 - ongoing
Data format	JSON
Related test cases	TC1.3.1, TC1.6.2

10.2.5 Separate, cross-platform datasets

DS.PP.01

Dataset ID	DS.PP.01
Data element	Plug-and-play asset data
Data description	Within the context of T3.3, Asset Data is a structured catalog of all data fields that describe flexible energy assets (devices or systems) within the Bluesun web-app. It defines each field's name, label, type, characterization (mandatory, recommended, optional), and weight factor. This data represents the nominal characteristics and operational constraints of assets (e.g., batteries, PV systems, energy meters, etc.) that have to be seamlessly integrated into HEMSs/BEMSs networks and eventually into the OPENTUNITY data space. They are collected directly through the web-app's asset registration forms, or automatically via API ingestion or through Digital Product Passport (DPP) imports, as provided by Economic Operators (EOs). The Asset Data is maintained centrally in the web-app to ensure consistency in scoring and evaluation. It underpins the Completeness Score KPI, which quantifies the richness of asset-data submitted. These data are relevant for demonstration activities, since they allow pilot sites to benchmark the quality of asset information and validate plug-and-play onboarding.
Confidentiality	Public
Access	Plug-and-play asset data is facilitated through the Bluesun web-app, which exposes it in two complementary ways. First, Economic Operators interact with HTML form interfaces to input or review the fields directly. Second, the data are made available programmatically through a REST API, enabling project partners to query asset-data in JSON format. API access requires a valid API key, issued upon registration, ensuring that only authorized users can retrieve the data. Additionally, future DPP imports are supported via URL endpoints, again secured by API keys. Overall, access is open for project partners under controlled authentication,
Source of data	Datasheets, Operating Instructions, Service Manuals, Modbus register maps etc. from asset vendors
Measurement units	Various (specific to asset characteristic)
Resolution	Static data
Data reception frequency	Static data
Time coverage	2025
Data format	JSON
Related test cases	TC.PP.01

10.3 Annex 3: KPIs

10.3.1 Horizontal KPIs

KPI.RTTR.01

<table>
<tr><td>KPI ID</td><td>KPI. RTTR.01</td></tr>
<tr><td>KPI Name</td><td>Average capacity increase by dynamic line rating</td></tr>
<tr><td>Associated strategic objective(s)</td><td>SO1. Decarbonization of EU society
SO3. Ensure quality of supply in a context of increase of RES</td></tr>
<tr><td>Associated OPENTUNITY innovation</td><td>Low-cost real-time thermal rating</td></tr>
<tr><td>Associated TC(s)</td><td>TC1.4.1, TC1.4.2</td></tr>
<tr><td>Responsible partner(s)</td><td>ICCS</td></tr>
<tr><td>KPI Description</td><td>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</td></tr>
<tr><td>KPI Formula</td><td>$$\Delta P_{av}^{max} = \sqrt{3}\, V_{nom} \frac{\sum_{i=1}^{N} I_{max,\ dynamic} - I_{max,\ static}}{N}$$</td></tr>
<tr><td>Formula variables</td><td>• $I_{max,\ dynamic}$: 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</td></tr>
<tr><td>KPI Unit</td><td>MVA</td></tr>
<tr><td>Baseline</td><td>0 MVA</td></tr>
<tr><td>Target</td><td>5 MVA</td></tr>
<tr><td>Calculation steps</td><td>
<table>
<tr><td></td><td>Description</td><td>Responsible</td></tr>
<tr><td>STEP 1</td><td>Provide static line rating $I_{max,\ static}$</td><td>Pilot site leader (HEDNO, ANELL)</td></tr>
<tr><td>STEP 2</td><td>Collect all dynamic ratings computed after deployment of innovation</td><td>ICCS</td></tr>
<tr><td>STEP 3</td><td>Compute $I_{max,\ dynamic}$ and KPI</td><td>ICCS</td></tr>
</table>
</td></tr>
</table>

KPI.RTTR.02

KPI ID	KPI.RTTR.02
KPI Name	Maximum line temperature underestimation
Associated strategic objective(s)	SO1. Decarbonization of EU society SO3. Ensure quality of supply in a context of increase of RES
Associated OPENTUNITY innovation	Low-cost real-time thermal rating
Associated TC(s)	TC1.4.1, TC1.4.2
Responsible partner(s)	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	$Max\ Temperature\ Underestimation(°C) = \max_{i=1:N}(\lvert T_{measured} - T_{\text{estimated}}\rvert)I_i$
Formula variables	• $T_{\text{estimated}}$: 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: Binary, 0 if the temperature is overestimated, 1 if underestimated
KPI Unit	˚C
Baseline	Greek pilot: N/A, Spanish pilot: 68.05˚C
Target	$Max\ Temperature\ Underestimation$ < 5 ˚C
Calculation steps	

	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.AAM.01

KPI ID	KPI.AAM.01
KPI Name	Accuracy on asset condition
Associated strategic objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Associated OPENTUNITY innovation	Advanced asset management
Associated TC(s)	TC1.5.1, TC1.5.2 TC1.5.3, TC1.5.4
Responsible partner(s)	ICCS
KPI Description	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/TSO
KPI Formula	$$Accuracy = 100\frac{\sum_{i=1}^{N} I_i}{N}$$
Formula variables	• I_i: Binary equal to 1 if the prediction condition category is the actual category provided by the DSO/TSO • N: Number of samples
KPI Unit	%
Baseline	0%
Target	80%
Calculation steps	

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

KPI.GPO.01

KPI ID	KPI.GPO.01
KPI Name	Investment deferral from optimal use of flexibility
Associated strategic objective(s)	SO1. Decarbonization of EU society SO3. Ensure quality of supply in a context of increase of RES
Associated OPENTUNITY innovation	Grid planning methodologies
Associated TC(s)	TC1.7.1, TC1.7.2
Responsible partner(s)	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	$\Delta T = \mathrm{T_{R\&I}} - \mathrm{T_{base}}$
Formula variables	• $\mathrm{T_{base}}$: Time of investment in years, in the BAU scenario • $\mathrm{T_{R\&I}}$: Time of investment in years, when flexibility is installed and optimized
KPI Unit	Years
Baseline	0
Target	2
Calculation steps	

	Description	Responsible
STEP 1	Provide cost of network upgrade, historical load and RES data, flexibility assets, flexibility costs, and business as usual methodology on network upgrades.	Pilot site leader (HEDNO, EL, EP)
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.GPO.02

KPI ID	KPI.GPO.02
KPI Name	Cost reduction due to the deferral of BAU grid upgrade
Associated strategic objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Associated OPENTUNITY innovation	Grid planning methodologies
Associated TC(s)	TC1.7.1, TC1.7.2
Responsible partner(s)	ICCS
KPI Description	The KPI calculates the cost reduction due to the deferral in the System Operator investments to replace or upgrade the network, by using BAU procedures, such as building new distribution 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	$$\text{Cost\_}reduction = \frac{Cost_{BAU} - Cost_{Flexibilty}}{Cost_{BAU}} \cdot 100$$
Formula variables	• $Cost_{reduction}$: Reinforcement cost when not upgrading the power grid due to utilization of the local flexibility market. • $Cost_{BAU}$: Reinforcement cost in the BAU scenario. • $Cost_{Flexibility}$: Grid reinforcement cost when considering the use of flexibility
KPI Unit	%
Baseline	0%
Target	10%
Calculation steps	

	Description	Responsible
STEP 1	Determine the power grid investments within a business as usual (BAU) scenario	ICCS, HEDNO, EL, EP
STEP 2	Calculate the cost when considering flexibility	ICCS
STEP 3	By using the formula provided before, the net cost reduction associated with using local flexibility market will be calculated	ICCS
STEP 4	The calculated net cost reduction will be compared with the target value that is set for this KPI to draw the appropriate conclusions	ICCS

KPI.GPO.03

KPI ID	KPI.GPO.03
KPI Name	Decrease in investment costs
Associated strategic objective(s)	SO1. Decarbonization of EU society SO3. Ensure quality of supply in a context of increase of RES
Associated OPENTUNITY innovation	Grid planning methodologies
Associated TC(s)	TC1.4.1, TC4.5.1
Responsible partner(s)	ICCS
KPI Description	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 Formula	$\Delta P_{RES} = 100 \frac{C_{BAU} - C_{R\&I}}{C_{BAU}}$
Formula variables	• $C_{R\&I}$: Cost of network upgrades estimated in the pilot with optimal scheduling of flexibility and network investments • C_{BAU}: Cost of network upgrades estimated with existing methodologies applied in each pilot
KPI Unit	%
Baseline	0%
Target	5%
Calculation steps	

	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 network upgrades considering flexibility sources availability	ICCS
STEP 4	Compute KPI	ICCS

KPI.GPO.04

KPI ID	KPI.GPO.04
KPI Name	Increase in RES hosting capacity
Associated strategic objective(s)	SO1. Decarbonization of EU society SO3. Ensure quality of supply in a context of increase of RES
Associated OPENTUNITY innovation	Grid planning methodologies
Associated TC(s)	TC2.1.1, TC4.5.1
Responsible partner(s)	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	$\Delta C_{RES} = 100\dfrac{\mathrm{RES}_{\mathrm{capacity}_{\mathrm{R\&I}}} - \mathrm{RES}_{\mathrm{capacity}_{BaU}}}{\mathrm{RES}_{\mathrm{capacity}_{BAU}}}$
Formula variables	• $\mathrm{RES}_{\mathrm{capacity}_{\mathrm{R\&I}}}$: Penetration of renewables with network planning that considers flexibility optimization • $\mathrm{RES}_{\mathrm{capacity}_{\mathrm{BaU}}}$: Penetration of renewables with network planning in a BAU scenario
KPI Unit	%
Baseline	0%
Target	5%
Calculation steps	

	Description	Responsible
STEP 1	Provide cost of network upgrade, historical load and RES data, flexibility assets, flexibility costs and existing RES hosting capacity 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 upgrades considering flexibility sources availability	ICCS
STEP 4	Compute KPI	ICCS

KPI.HEMS.01

KPI ID	KPI.HEMS.01
KPI Name	Demand Forecasting Accuracy
Associated strategic objective(s)	SO2. Citizen and stakeholder empowerment
Associated OPENTUNITY innovation	HEMS and BEMS flexibility and DR optimization including initial settings algorithms
Associated TC(s)	TC1.8.1.1, TC1.8.1.2, TC1.8.1.3
Responsible partner(s)	HYP
KPI Description	The mean absolute error (over a given time period) between the actual and the forecasted demand (baseline).
KPI Formula	$MAE_{forecast} = \frac{\sum_{t=1}^{T} \lvert P_{act,t} - P_{b,t} \rvert}{T}$
Formula variables	• $MAE_{forecast}$: 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 ($t \in 1, \dots, T$)
KPI Unit	kW
Baseline	Actual power consumption profile
Target	Short-term: <10%, Mid-term: <30%

Calculation steps

	Description	Responsible
STEP 1	Data made available to HYP by pilot partners	HYP, HEDNO, ANELL, AEM
STEP 2	Forecasting and comparison with collected data	HYP
STEP 3	Calculation of the KPI	HYP

KPI.HEMS.02

<table>
<tr><td>KPI ID</td><td>KPI.HEMS.02</td></tr>
<tr><td>KPI Name</td><td>Flexibility delivery precision</td></tr>
<tr><td>Associated strategic objective(s)</td><td>SO2. Citizen and stakeholder empowerment</td></tr>
<tr><td>Associated OPENTUNITY innovation</td><td>HEMS and BEMS flexibility and DR optimization including initial settings algorithms</td></tr>
<tr><td>Associated TC(s)</td><td>TC1.8.3.1, TC1.8.3.2, TC1.8.3.3, TC1.10.1, TC1.10.3</td></tr>
<tr><td>Responsible partner(s)</td><td>HYP</td></tr>
<tr><td>KPI Description</td><td>This KPI measures the extent to which the flexibility has been delivered according to the initial bid that had been made by the prosumer</td></tr>
<tr><td>KPI Formula</td><td>$$FD_{error} = \frac{\sum_{t=1}^{T} \left|P_{del,t} - P_{bid,t}\right| \cdot I_t}{\sum_{t=1}^{T} P_{bid,t}} \cdot 100$$</td></tr>
<tr><td>Formula variables</td><td>

FD_{error}: percentage error which expresses the degree of under-delivery of flexibility that has been bidded to the flexibility market.
$P_{del,t}$: 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 ($t \in 1, \dots, T$)

</td></tr>
<tr><td>KPI Unit</td><td>%</td></tr>
<tr><td>Baseline</td><td>N/A since no flexibility provision before demonstration</td></tr>
<tr><td>Target</td><td>0%</td></tr>
<tr><td>Calculation steps</td><td>
<table>
<tr><th></th><th>Description</th><th>Responsible</th></tr>
<tr><td>STEP 1</td><td>Data made available to HYP by pilot partners</td><td>HYP, HEDNO, ANELL, AEM</td></tr>
<tr><td>STEP 2</td><td>Flexibility estimation</td><td>HYP</td></tr>
<tr><td>STEP 3</td><td>Delivery/Dispatch</td><td>HYP</td></tr>
<tr><td>STEP 4</td><td>Calculation based on the above formula</td><td>HYP[1]</td></tr>
</table>
</td></tr>
</table>

[1] From a market perspective, the evaluation of flexibility delivery should be performed officially by a neutral party such a market operator. An FSP that verifies the flexibility delivery the way it is done here may be prone to gaming, i.e. strategically adapting the numbers to increase its own revenue. However, this is part of a research project and this KPI reflects more of a data evaluation exercise. Partners in the OPENTUNITY project are aware that from a market and regulatory point of view, such KPI should be handled by an appropriate entity in a real-world setting.

KPI.HEMS.03

KPI ID	KPI.HEMS.03		
KPI Name	Flexibility potential		
Associated strategic objective(s)	SO2. Citizen and stakeholder empowerment		
Associated OPENTUNITY innovation	HEMS and BEMS Flexibility and DR optimization including initial settings algorithms		
Associated TC(s)	TC1.8.1.1, TC1.8.1.2, TC1.8.1.3, TC1.8.2.1, TC1.8.2.2, TC1.8.2.3, TC1.10.1, TC1.10.3		
Responsible partner(s)	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	$$E_{flex} = \sum_{t=1}^{T}(P_{b,t} - P_{opt,t})$$		
Formula variables	• 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 ($t \in 1, \dots, T$)		
KPI Unit	kWh		
Baseline	0 kWh		
Target	E_{flex} > 0 kWh		
Calculation steps		**Description**	**Responsible**
	STEP 1	Data made available to HYP by pilot partners	HYP, HEDNO, ANELL, AEM
	STEP 2	Baseline estimation	HYP
	STEP 3	Flexibility optimization	HYP
	STEP 4	Calculation of the KPI	HYP

KPI.HEMS.04

KPI ID	KPI.HEMS.04
KPI Name	GHG Reduction
Associated strategic objective(s)	SO2. Citizen and stakeholder empowerment
Associated OPENTUNITY innovation	HEMS and BEMS Flexibility and DR optimization including initial settings algorithms
Associated TC(s)	TC1.8.2.1, TC1.8.2.2, TC1.8.2.3, TC1.8.3.1, TC1.8.3.2, TC1.8.3.3
Responsible partner(s)	HYP
KPI Description	Reduction in GHG emissions which stems from DR
KPI Formula	$$GHG_{Reduction} = EF \cdot \sum_{t=1}^{T}(P_{act,t} - P_{DR,t})$$
Formula variables	• $GHG_{Reduction}$: GHG reduction which results from DR (only for demand reduction case) • EF: Emission factor (275 gCO2eq/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 ($t \in 1, \dots, T$)
KPI Unit	gCO_2eq
Baseline	GHG emissions for actual prosumer demand profile
Target	Maximization of GHG reduction
Calculation steps	

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

KPI.HEMS.05

KPI ID	KPI.HEMS.05
KPI Name	Load Reduction/Increase
Associated strategic objective(s)	SO2. Citizen and stakeholder empowerment
Associated OPENTUNITY innovation	HEMS and BEMS Flexibility and DR optimization including initial settings algorithms
Associated TC(s)	TC1.8.2.1, TC1.8.2.2, TC1.8.2.3, TC1.8.3.1, TC1.8.3.2, TC1.8.3.3
Responsible partner(s)	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 KPI expresses energy savings.
KPI Formula	$$E_{change} = \sum_{t=1}^{T} (P_{act,t} - P_{DR,t})$$
Formula variables	• 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 ($t \in 1, \dots, T$)
KPI Unit	kWh
Baseline	Actual demand profile of a prosumer
Target	No specific target
Calculation steps	

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

KPI.HEMS.06

KPI ID	KPI.HEMS.06
KPI Name	Rate of Successful DR Events
Associated strategic objective(s)	SO2. Citizen and stakeholder empowerment
Associated OPENTUNITY innovation	HEMS and BEMS Flexibility and DR optimization including initial settings algorithms
Associated TC(s)	TC1.8.3.1, TC1.8.3.2, TC1.8.3.3
Responsible partner(s)	HYP
KPI Description	The rate of successful DR events compared to the number of total DR requests
KPI Formula	$$R_{S,DR} = \frac{N_{S,DR}}{N_{total,DR}} \cdot 100\%$$
Formula variables	• $R_{S,DR}$: Rate of successful DR events (percentage) • $N_{S,DR}$: Number of successful DR events • $N_{total,DR}$: Number of total DR requests
KPI Unit	Percentage (%)
Baseline	N/A
Target	>85%
Calculation steps	

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

KPI.HEMS.07

<table>
<tr><td>KPI ID</td><td>KPI.HEMS.07</td></tr>
<tr><td>KPI Name</td><td>Thermal Comfort Violation</td></tr>
<tr><td>Associated strategic objective(s)</td><td>SO2. Citizen and stakeholder empowerment</td></tr>
<tr><td>Associated OPENTUNITY innovation</td><td>HEMS and BEMS Flexibility and DR optimization including initial settings algorithms</td></tr>
<tr><td>Associated TC(s)</td><td>TC1.9.1, TC1.9.2</td></tr>
<tr><td>Responsible partner(s)</td><td>HYP</td></tr>
<tr><td>KPI Description</td><td>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.</td></tr>
<tr><td>KPI Formula</td><td>$TC = \sum_{t=1}^{T}(\theta_{limit,l,t} - \theta_{actual,t}) \cdot I_{l,t} \cdot \Delta t + \sum_{t=1}^{T}(\theta_{actual,t} - \theta_{limit,u,t}) \cdot I_{u,t} \cdot \Delta t$</td></tr>
<tr><td>Formula variables</td><td>
• TC: Thermal comfort violation, as the 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
• $\theta_{limit,l,t}$: Lower temperature limit at time t
• $\theta_{limit,u,t}$: Upper temperature limit at time t
• $I_{l,t}$: Indicator variable which shows the existence of a lower temperature limit violation at time t (can be either zero or one). 0: above lower limit. 1: below lower limit.
• $I_{u,t}$: Indicator variable which shows the existence of an upper temperature limit violation at time t (can be either zero or one). 0: below upper limit. 1: above upper limit.
• t: time index ($t \in 1, \ldots, T$)</td></tr>
<tr><td>KPI Unit</td><td>˚C·h</td></tr>
<tr><td>Baseline</td><td>N/A</td></tr>
<tr><td>Target</td><td>< 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)</td></tr>
<tr><td>Calculation steps</td><td>
<table>
<tr><th></th><th>Description</th><th>Responsible</th></tr>
<tr><td>STEP 1</td><td>Data made available to HYP by pilot partners</td><td>HYP, HEDNO, ANELL</td></tr>
<tr><td>STEP 2</td><td>Identify comfort boundaries</td><td>HYP</td></tr>
<tr><td>STEP 3</td><td>Demonstration of DR with thermal comfort constraints</td><td>HYP</td></tr>
<tr><td>STEP 4</td><td>Calculation based on the above formula</td><td>HYP</td></tr>
</table>
</td></tr>
</table>

KPI.FM.01

<table>
<tr><td>KPI ID</td><td colspan="3">KPI.FM.01</td></tr>
<tr><td>KPI Name</td><td colspan="3">Local average voltage deviation index (AVDI)</td></tr>
<tr><td>Associated strategic objective(s)</td><td colspan="3">SO3. Ensure quality of supply in a context of increase of RES</td></tr>
<tr><td>Associated OPENTUNITY innovation</td><td colspan="3">Flexibility market design and management</td></tr>
<tr><td>Associated TC(s)</td><td colspan="3">TC1.10.1</td></tr>
<tr><td>Responsible partner(s)</td><td colspan="3">HEDNO</td></tr>
<tr><td>KPI Description</td><td colspan="3">The proposed metric is designed to evaluate the effectiveness of energy system operators' participation to a local energy flexibility market. This will be achieved, by introducing an indicator for the voltages on the system's buses.</td></tr>
<tr><td>KPI Formula</td><td colspan="3">The AVDI measures the average deviation of voltage levels from the desired or nominal voltage within the distribution network.
$$AVDI = \frac{1}{N}\sum_{i=1}^{N}|V_i - V_{nominal}|$$</td></tr>
<tr><td>Formula variables</td><td colspan="3">• $V_i[pu]$: Measured voltage at bus i
• $V_{nominal}[pu]$: Nominal voltage level of the local energy system
• N: Number of the buses in the local energy system</td></tr>
<tr><td>KPI Unit</td><td colspan="3">pu</td></tr>
<tr><td>Baseline</td><td colspan="3">AVDI>=0.05 pu</td></tr>
<tr><td>Target</td><td colspan="3">AVDI<0.05 pu</td></tr>
<tr><td rowspan="5">Calculation steps</td><td></td><td>Description</td><td>Responsible</td></tr>
<tr><td>STEP 1</td><td>Historical data on energy production and consumption within the energy distribution networks will be collected.</td><td>HEDNO/IPTO</td></tr>
<tr><td>STEP 2</td><td>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.</td><td>HEDNO/IPTO, ICCS</td></tr>
<tr><td>STEP 3</td><td>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.</td><td>HEDNO/IPTO, HYP, NODES</td></tr>
<tr><td>STEP 4</td><td>Power flow studies will be conducted after the deployment of the local energy flexibility market to calculate the AVDI and evaluate its effectiveness for the local operators.</td><td>HEDNO/IPTO, ICCS</td></tr>
</table>

KPI.FM.02

KPI ID	KPI.FM.02
KPI Name	TSO/DSO coordination efficiency
Associated strategic objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Associated OPENTUNITY innovation	Integration of DSO and TSO ICT infrastructures into energy management systems
Associated TC(s)	TC1.10.1
Responsible partner(s)	HEDNO, IPTO, HYP, NODES
KPI Description	This KPI serves to examine the efficiency of the coordination scenarios in terms of problem resolution, time efficiency and grid management. The KPI evaluates the number of critical flexibility buy orders solved and activated flexibility volume according to market timeline in yellow/red light scenarios – day-ahead and intraday
KPI Formula	$KPI_{crit.Flex} = \frac{F_{SO\ critical\ requests\ solved}}{F_{SO\ critical\ requests\ unsolved}} \cdot 100$ $KPI_{Flex\ vol} = \frac{F_{Flex\ vol\ activated}}{F_{Request}} \cdot 100$
Formula variables	• $F_{SO\ critical\ requests\ solved}$: Solved flexibility requests by the DSO/TSO • $F_{SO\ critical\ requests\ unsolved}$: Unsolved flexibility requests by the DSO/TSO • $F_{Flex\ vol\ activated}$: Activated flexibility volume per DSO/TSO • $F_{Request}$: Requested flexibility volume per DSO/TSO
KPI Unit	%
Baseline	$KPI_{crit.Flex} = 0\%$ $KPI_{Flex\ vol} = 0\%$
Target	$F_{SO\ critical\ requests\ unsolved} < 5$
Calculation steps	

	Description	Responsible
STEP 1	System operators submit flexibility request on the flexibility market	HEDNO/IPTO
STEP 2	FSP submits their bids and after market clears, FSP gets flexibility orders to activate their assets	HYP
STEP 3	KPI is calculated	HYP, NODES

KPI.FM.03

KPI ID	KPI.FM.03
KPI Name	Potential offered flexibility
Associated strategic objective(s)	SO2. Citizen and stakeholder empowerment
Associated OPENTUNITY innovation	Flexibility market design and management
Associated TC(s)	TC1.10.3
Responsible partner(s)	AEM, SUPSI, NODES
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. $$Flex_{PO} = \sum_{i=1}^{N}\sum_{t=1}^{T} P.flex_{PO_{i,t}}$$
Formula variables	• $\mathrm{P.flex}_{\mathrm{PO}_{\mathrm{i,t}}}$: 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
KPI Unit	kW
Baseline	0 kW
Target	$Flex_{PO} > 1$ kW

Calculation steps:

	Description	Responsible
STEP 1	The DSO 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.	AEM
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 FSP at the flexibility market new data will be collected and evaluated.	AEM, SUPSI
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.	AEM, SUPSI, NODES
STEP 4	The KPI for a given set of flexible resources at an examined time period will be defined and evaluated.	AEM, SUPSI, NODES

KPI.FM.04

KPI ID	KPI.FM.04
KPI Name	Type of flexibility provider (TFP)
Associated strategic objective(s)	SO2. Citizen and stakeholder empowerment
Associated OPENTUNITY innovation	Flexibility market design and management
Associated TC(s)	TC1.10.1, TC1.10.3
Responsible partner(s)	HYP, SUPSI
KPI Description	This indicator reflects how versatile the pilot is in leveraging flexibility from different technologies. If and how different types of technologies can be accessed and utilized during the demonstration phase depends on the number of different technologies that are available in the region of the pilot as well as on the general capabilities of the pilot. This KPI is measured as the relation (in %) between the number of different technologies leveraged and the number of types of technologies initially targeted by the pilot. The following technologies currently considered for this KPI are: renewables, conventional generators connected to the distribution or transmission system, storage, gensets, EVs, heat pumps, electric boilers, and aggregated consumer load.
KPI Formula	$$TFP = \frac{N_{leverage.technology}}{N_{target.technology}} \cdot 100$$
Formula variables	• $N_{leverage.technology}$: Number of different technology types utilized during the demonstration • $N_{target.technology}$: Number of different technology types available in the pilot
KPI Unit	%
Baseline	No baseline is available for this KPI, as the flexibility management service is being introduced for the first time
Target	TFP > 12.5%

Calculation steps

	Description	Responsible
STEP 1	The system operator will consider which types of flexibility providers are available in the area of interest	HEDNO/IPTO (GR pilot), AEM (CH 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	HEDNO/IPTO (GR pilot), AEM (CH pilot)
STEP 3	For a given set of time horizons, participation results in the local flexibility market will be collected to calculate the KPI	NODES
STEP 4	The KPI for a given indicative set of time horizons will be calculated	NODES

KPI.FM.05

KPI ID	KPI.FM.05		
KPI Name	Flexibility used for ancillary services and balancing		
Associated strategic objective(s)	SO3. Ensure quality of supply in a context of increase of RES		
Associated OPENTUNITY innovation	Flexibility market design and management		
Associated TC(s)	TC1.10.1		
Responsible partner(s)	HEDNO, IPTO, HYP		
KPI Description	Depending on market set-up it is worthwhile evaluating the required/activated flexibility of each system operator through the bids and trades of FSPs. This KPI will define the ratio of activated flexibility from the system operators' perspective, used to resolve congestion and balancing issues once the Local Flexibility Market becomes operational. The calculation will be based on the amount of flexibility identified as needed by the system operators locally and supplied through the FSP offers in the LFM.		
KPI Formula	$KPI_{DSO.Flex} = \frac{F_{FSP\ bid}}{F_{DSO\ request}} \cdot 100$ $KPI_{TSO.Flex} = \frac{F_{FSP\ bid}}{F_{TSO\ request}} \cdot 100$		
Formula variables	• $F_{DSO\ request}$: Amount of flexibility requested by DSO • $F_{TSO\ request}$: Amount of flexibility requested by TSO • $F_{FSP\ bid}$: Amount of flexibility offered by FSP		
KPI Unit	%		
Baseline	For DSO requests: Expected initial ratio: 50% when LFM becomes operational For TSO requests: Expected initial ratio: 10% when LFM becomes operational		
Target	DSO: ≥50% during project | ≥70% as final target TSO: ≥10% during project | ≥20% as final target		
Calculation steps		**Description**	**Responsible**
	STEP 1	The TSO will consider which types of flexibility providers are available in the area of interest.	HEDNO/IPTO
	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.	HEDNO/IPTO
	STEP 3	FSP volume bid in the local flexibility market will be collected to calculate the KPI	HYP
	STEP 4	The KPI will be calculated	HEDNO/IPTO, HYP

KPI.NILM.01

KPI ID	KPI.NILM.01
KPI Name	F1 score of NILM model
Associated strategic objective(s)	SO1. Decarbonization of EU society SO2. Citizen and stakeholder empowerment
Associated OPENTUNITY innovation	AI non-intrusive load monitoring algorithms
Associated TC(s)	TC1.2.1, TC1.2.2, TC1.2.3, TC1.2.4
Responsible partner(s)	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	$Precision = \frac{TP}{TP + FP}$ $Recall = \frac{TP}{TP + FN}$ $F1 = \frac{2 \ x \ Precision \ x \ Recall}{Precision + Recall}$
Formula variables	• TP: True positives • FP: False positives • FN: False negatives
KPI Unit	Percentage (%)
Baseline	80%
Target	>85%

Calculation steps

	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.	HEDNO, EL/EP, ANELL, AEM
STEP 2	Split the dataset into training and testing sets. Train a prediction model using the collected historical data	ETRA

		(train dataset) and test the prediction model using the testing set.	
	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.SE.01

<table>
<tr><td>KPI ID</td><td>KPI.SE.01</td></tr>
<tr><td>KPI Name</td><td>Variability of the voltage</td></tr>
<tr><td>Associated strategic objective(s)</td><td>SO1. Decarbonization of EU society
SO2. Citizen and stakeholder empowerment</td></tr>
<tr><td>Associated OPENTUNITY innovation</td><td>Topology identification and state estimation via machine learning</td></tr>
<tr><td>Associated TC(s)</td><td>TC1.1.1, TC1.1.2</td></tr>
<tr><td>Responsible partner(s)</td><td>ETRA</td></tr>
<tr><td>KPI Description</td><td>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.</td></tr>
<tr><td>KPI Formula</td><td>$$\%Reg_{(down)} = \frac{V_{(no-load)} - V_{(full-load)}}{V_{(no-load)}} \cdot 100$$ $$\%Reg_{(up)} = \frac{V_{(no-load)} - V_{(full-load)}}{V_{(full-load)}} \cdot 100$$</td></tr>
<tr><td>Formula variables</td><td>• $V_{(no-load)}$: No-load terminal voltage
• $V_{(full-load)}$: Terminal voltage drop when application of a resistive load</td></tr>
<tr><td>KPI Unit</td><td>Percentage (%)</td></tr>
<tr><td>Baseline</td><td>±10%</td></tr>
<tr><td>Target</td><td>±5%</td></tr>
<tr><td>Calculation steps</td><td>
<table>
<tr><th></th><th>Description</th><th>Responsible</th></tr>
<tr><td>STEP 1</td><td>Gather historical electrical grid information about voltage in the lines affected by voltage variations</td><td>ANELL, AEM</td></tr>
<tr><td>STEP 2</td><td>Calculate grid state estimation for near-future</td><td>ETRA</td></tr>
<tr><td>STEP 3</td><td>Apply N-1 contingency analysis on DER elements. Calculate $\%Reg_{(down)}$ and $\%Reg_{(up)}$ for each bus in the topology. Show problems in GUI (out of thresholds)</td><td>ETRA</td></tr>
<tr><td>STEP 4</td><td>Apply changes to the network: curtail, request flexibility, etc.</td><td>ETRA</td></tr>
<tr><td>STEP 5</td><td>Calculate $\%Reg_{(down)}$ and $\%Reg_{(up)}$ and compare with baseline</td><td>ETRA</td></tr>
</table>
</td></tr>
</table>

KPI.SE.02

KPI ID	KPI.SE.02
KPI Name	Mean Absolute Percentage Error (MAPE) of state estimation model
Associated strategic objective(s)	SO1. Decarbonization of EU society SO2. Citizen and stakeholder empowerment
Associated OPENTUNITY innovation	Topology identification and state estimation via machine learning
Associated TC(s)	TC1.3.1, TC1.3.2, TC1.3.3
Responsible partner(s)	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	$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\frac{\lvert y_i - \hat{y}_i\rvert}{\lvert y_i\rvert}$$
Formula variables	• n is the number of network buses • y_i represents the actual state value at bus i • $\hat{y}_i$ represents the estimated state value at bus i
KPI Unit	Percentage
Baseline	Voltage: 2% Angle: 5% Power flows: 5% Loads: 10%
Target	Voltage: 1% Angle: 2% Power flows: 2% Loads: 5%
Calculation steps	

	Description	Responsible
STEP 1	Gather historical electrical information on loads and generators (P & Q) (D-X)	EP/EL, ANELL, AEM
STEP 2	Build P & Q forecast models for each load and generator, considering exogenous variables (weather, calendar, etc.) (D-X)	ETRA
STEP 3	Obtain RT values from selected buses (D)	EP/EL, ANELL, AEM

	STEP 4	Calculate grid SE for near-future using forecast model and available RT measurements (D)	ETRA
	STEP 5	After a while, obtain RT value from loads, generators and buses (D+1)	EP/EL, ANELL, AEM
	STEP 6	Compare obtained RT values with those calculated using SE. Calculate MAPE	ETRA

KPI.TI.01

KPI ID	KPI.TI.01		
KPI Name	Topology identification MAPE		
Associated strategic objective(s)	SO1. Decarbonization of EU society SO2. Citizen and stakeholder empowerment		
Associated OPENTUNITY innovation	Topology identification and state estimation via machine learning		
Associated TC(s)	TC1.6.1, TC1.6.2		
Responsible partner(s)	ETRA		
KPI Description	The aim of the KPI is to calculate the Mean Absolute Percentage Error (MAPE) to evaluate the accuracy of the Topology Identification module. In this scenario, MAPE is computed by taking the absolute difference between the estimated and actual topology of the system. This yields the average absolute discrepancy, expressed in percentage. A lower MAPE value indicates a more accurate Topology Identification. Conversely, a higher MAPE suggests that there is a greater level of discrepancy between the estimated and actual topology, which may be indicative of larger measurement errors or losses.		
KPI Formula	$MAPE = \frac{1}{n}\sum_{i=1}^{n}\frac{\lvert y_i - \hat{y}_i\rvert}{\lvert y_i\rvert}$		
Formula variables	• n is the total number of network loads and generators • y_i represents de actual state value a load and generator i • $\hat{y}_i$ represents the estimated state value at each load and generator i		
KPI Unit	Percentage (%)		
Baseline	0%		
Target	<40%		
Calculation steps		Description	Responsible
	STEP 1	Gather historical electrical information on loads and generators (P & Q) (D-X)	AEM, ANELL
	STEP 2	Build P & Q forecast models for each load and generator, considering exogenous variables (weather, calendar, etc.) (D-X)	ETRA
	STEP 3	Obtain real time values from selected buses (D)	AEM, ANELL
	STEP 4	Calculate grid state estimation for near-future using forecast model and available real-time measurements (D)	ETRA
	STEP 5	After a while, obtain real time value from loads, generators and buses (D+1)	AEM, ANELL
	STEP 6	Compare obtained real time values with those calculated using state estimation. Calculate MAPE	ETRA
	STEP 7	Apply changes in topology and check if MAPE is enhanced. Present information about potential errors in the current topology based on this	ETRA

10.3.2 Greek pilot KPIs

KPI.GR.01

KPI ID	KPI.GR.01
KPI Name	Measurement-Consistent Mean Absolute Percentage Error (MC-MAPE)
Associated strategic objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Associated OPENTUNITY innovation	Topology identification and state estimation via machine learning
Associated TC(s)	TC1.3.4
Responsible partner(s)	ICCS
KPI Description	Mean Absolute Percentage Error (MAPE) is a metric used to evaluate the accuracy of the State Estimation (SE) model in terms of bus voltage magnitudes during real-time operation. In a controlled test environment (e.g., using Monte Carlo trials), it is computed as the mean absolute difference between the estimated and the true voltage magnitude values, where the latter are obtained from a solved power flow. In real-world operation, however, this direct calculation is infeasible since the true system state cannot be exactly determined due to the inherent limitations of measurements (errors, delays, and uncertainty). To address this issue, a modified version of MAPE, termed Measurement-Consistent MAPE (MC-MAPE), is introduced. MC-MAPE is evaluated only at nodes equipped with Advanced Metering Infrastructure (AMI) devices, which provide real-time measurements of bus voltage magnitudes and power injections. The metric is defined as the mean of the absolute differences between (i) the AMI measurement values and (ii) the corresponding values reconstructed from a power flow solution based on the estimated system state, normalized by the AMI measurements. To avoid instability due to zero or near-zero denominators (particularly for power injections), the normalization uses the maximum between the AMI measurement value and a device-specific normalization factor. In this context, low MC-MAPE values indicate that the PMU-based SE model provides an output that is consistent with the data obtained from AMI devices, thus, serving as evidence of high accuracy. On the contrary, higher MAPE values highlight inconsistencies between AMI data and the projection of the estimated state into AMI measurements via power flow, which may be attributed to poor model accuracy, measurement errors, or both.
KPI Formula	$$MC-MAPE_i = \frac{1}{m}\sum_{j=1}^{m}\frac{\lvert h_j(\hat{\boldsymbol{x}}_i) - z_{j,i}\rvert}{\max\,(z_{j,i}, \eta_{d,j})} \times 100$$
Formula variables	• i: time interval of SE execution • m: number of AMI measurements • $z_{j,i}$: j -th measurement value at time interval i • $\hat{\boldsymbol{x}}_i$: estimated state at time interval i • $\eta_{d,j}$: normalization factor of device d for the j -th measurement
KPI Unit	Percentage (%)
Baseline	10-15%
Target	1%
Calculation steps	<table><tr><th></th><th>Description</th><th>Responsible</th></tr><tr><td>STEP 1</td><td>Gather real-time measurements from PMU and AMI devices installed in field</td><td>HEDNO</td></tr></table>

	STEP 2	Use the developed deep neural network (DNN) model to perform topology identification	ICCS
	STEP 3	Use the developed DNN model to perform state estimation based on the PMU measurements and the estimated topology	ICCS
	STEP 4	Calculate MC-MAPE using the estimated system state and the AMI measurements	ICCS

KPI.GR.02

KPI ID	KPI.GR.02
KPI Name	Topology match accuracy
Associated strategic objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Associated OPENTUNITY innovation	Topology identification and state estimation via machine learning
Associated TC(s)	TC1.6.3
Responsible partner(s)	ICCS
KPI Description	Topology Match Accuracy (TMA) is a metric used to evaluate the accuracy of topology inference by the Topology Identification (TI) model. An estimated topology is considered correct only when the state (open/closed) of all switch-bearing lines matches the ground truth. TMA is then defined as the ratio of correctly matched topologies to the total number of evaluated cases, where each case corresponds to a specific time interval of TI execution. In real-world operation, TMA is updated at the subsequent time interval of TI execution, reflecting the estimated topology of the preceding interval. The actual system topology used to compute the metric can be obtained by crosschecking with the HEDNO control centre, since all switches and the connected PVs at medium voltage (MV) level are remotely monitored. While the control centre may not provide immediate information about topology changes, the correct state can be retrieved after a short delay. Additionally, real-time data from AMI devices can be leveraged to infer customer connectivity at the corresponding nodes. Since the estimated system topology serves as a critical input to the SE model, the TMA value should be close to 100% to guarantee a high level of reliability in system monitoring.
KPI Formula	$$TMA = \frac{1}{n}\sum_{i=1}^{n} b_i \times 100$$
Formula variables	• i: time interval of State Estimation execution • n: number of evaluated cases • b_i: binary indicator equal to 1 in case of a correctly estimated topology, 0 else
KPI Unit	Percentage (%)
Baseline	90%
Target	100%
Calculation steps	see table below

	Description	Responsible
STEP 1	Gather real-time measurements from PMU and AMI devices installed in field.	HEDNO
STEP 2	Use the developed deep neural network (DNN) model to perform topology identification	ICCS
STEP 3	Calculate TMA using the estimated and the actual system topology.	ICCS

10.3.3 Swiss pilot KPIs

KPI.CH.01

KPI ID	KPI.CH.01
KPI Name	Average amount of flexibility available from the energy community
Associated strategic objective(s)	SO2. Citizen and stakeholder empowerment SO3. Ensure quality of supply in the context of increase of RES
Associated OPENTUNITY innovation	HEMS and BEMS Flexibility and DR optimization including initial settings algorithms Flexibility market design and management
Associated TC(s)	TC5.1.1, TC5.2.1
Responsible partner(s)	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. 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.
KPI Formula	$\mu_{flex\ t} = \frac{\sum_n^N P_n}{N}$ $\mu_{flex\ mean} = \frac{\sum_t^T \mu_{flex\ t}}{T}$ $\sigma_{flex} = \sqrt{\frac{\sum_t^T (\mu_{flex\ t} - \mu_{flex\ mean})^2}{T}}$
Formula variables	• 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 over period T • σ_{flex}: standard deviation measuring the dispersion of power available
KPI Unit	kW
Baseline	No baseline is available for this KPI, as the flexibility management service is being introduced for the first time.
Target	Minimization
Calculation steps	<table><tr><th></th><th>Description</th><th>Responsible</th></tr><tr><td>STEP 1</td><td>Data collection on the flexibility available for the aggregator from the energy community assets for a given period.</td><td>HYP</td></tr><tr><td>STEP 2</td><td>Calculation of indicators</td><td>HYP</td></tr></table>

KPI.CH.02

KPI ID	KPI.CH.02
KPI Name	Average peak load reduction at the MV/LV transformer station
Associated strategic objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Associated OPENTUNITY innovation	Topology identification and state estimation via machine learning HEMS and BEMS Flexibility and DR optimization including initial settings algorithms Flexibility market design and management
Associated TC(s)	TC5.1.1, TC5.2.1
Responsible partner(s)	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	$y_{max} = \max_{t \in \mathcal{T}} y(t)$ $y_{max,ctrl} = \max_{t \in \mathcal{T}} y(t) + y_{flex}(t) = \max_{t} y_{ctrl}(t)$ $\text{KPI}_1 = y_{max} - y_{max,ctrl}$ $\text{KI}_1 = \Delta t \sum_{t=1}^{T} maximum\big(y(t) - y_{max,ctrl}, 0\big)$ $\text{KI}_2 = \text{KI}_1/\text{KPI}_1 \qquad \text{if } y_{max} > y_{max,ctrl}$
Formula variables	• 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
KPI Unit	KPI_1: kW KI_1: kWh KI_2: kWh/kW
Baseline	No baseline is available for this KPI, as the flexibility management service is being introduced for the first time.
Target	Since this KPI measures absolute energy volumes, no target can be fixed as this strongly depends on the nature of the peaks that will be shaved.
Calculation steps	

	Description	Responsible
STEP 1	Data collection from the secondary side of the transformer located upstream the energy community, before and after the peak reduction for a given time period T.	AEM
STEP 2	Data reception and calculation of the KPI	ETRA

KPI.CH.03

KPI ID	KPI.CH.03
KPI Name	Error in the prediction of electricity demand
Associated 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
Associated OPENTUNITY innovation	Topology identification and state estimation via machine learning HEMS and BEMS Flexibility and DR optimization including initial settings algorithms Flexibility market design and management
Associated TC(s)	TC5.1.1, TC5.2.1
Responsible partner(s)	AEM, ETRA
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	$AFE_{demand} = \frac{\sum_i^I RMSE_{forecasted\ demand\ i}}{I}$ $RMSE_{forecatsed\ demand\ i} = \sqrt{\frac{1}{T}\sum_t^T (E\ Actual_t - E\ Forecasted_t)^2}$
Formula variables	• 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
KPI Unit	kWh
Baseline	No baseline is available for this KPI, as the forecast service is being introduced for the first time.
Target	Minimization
Calculation steps	(see table below)

	Description	Responsible
STEP 1	Historical data provision for all the points 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.CH.04

KPI ID	KPI.CH.04
KPI Name	Error in the prediction of photovoltaic production
Associated strategic objective(s)	SO1. Decarbonization of EU society SO3. Ensure quality of supply in a context of increase of RES
Associated OPENTUNITY innovation	Topology identification and state estimation via machine learning.
Associated TC(s)	TC5.1.1, TC5.2.1
Responsible partner(s)	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. 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.
KPI Formula	$AFE_{production} = \frac{\sum_i^I RMSE_{forecasted\ demand\ i}}{I}$ $RMSE_{forecatsed\ production\ i} = \sqrt{\frac{1}{T}\sum_t^T (E\ Actual_t - E\ Forecasted_t)^2}$
Formula variables	• 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
KPI Unit	kWh
Baseline	No baseline is available for this KPI, as the forecast service is being introduced for the first time.
Target	Minimization
Calculation steps	see table below

	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.CH.05

<table>
<tr><td>KPI ID</td><td colspan="3">KPI.CH.05</td></tr>
<tr><td>KPI Name</td><td colspan="3">Flexibility activation accuracy</td></tr>
<tr><td>Associated strategic objective(s)</td><td colspan="3">SO3. Ensure quality of supply in a context of increase of RES</td></tr>
<tr><td>Associated OPENTUNITY innovation</td><td colspan="3">HEMS and BEMS Flexibility and DR optimization including initial settings algorithms.</td></tr>
<tr><td>Associated TC(s)</td><td colspan="3">TC5.1.1, TC5.2.1</td></tr>
<tr><td>Responsible partner(s)</td><td colspan="3">SUPSI</td></tr>
<tr><td>KPI Description</td><td colspan="3">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.</td></tr>
<tr><td>KPI Formula</td><td colspan="3">$$MAE = \frac{1}{T}\sum_{t\in T}\left|\frac{y(t)-x(t)}{x(t)}\right| \qquad \mathrm{T}:\{t: n_{activated} > 0\}$$</td></tr>
<tr><td>Formula variables</td><td colspan="3">• $y(t)$: observed profile of the flexible devices, during a flexibility call
• $x(t)$: 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</td></tr>
<tr><td>KPI Unit</td><td colspan="3">-</td></tr>
<tr><td>Baseline</td><td colspan="3">No baseline is available for this KPI, as the flexibility management service is being introduced for the first time.</td></tr>
<tr><td>Target</td><td colspan="3">0.3</td></tr>
<tr><td rowspan="6">Calculation steps</td><td></td><td>Description</td><td>Responsible</td></tr>
<tr><td>STEP 1</td><td>Before T:
Periodical collection of 15-minutes data related to the flexibilities available for the aggregation and to the meteorological situation</td><td>AEM, HYP, HIVE</td></tr>
<tr><td>STEP 2</td><td>Before T:
Performing of flexibility forecast and aggregation for time-slot T</td><td>SUPSI</td></tr>
<tr><td>STEP 3</td><td>@ T:
Activation of flexibility</td><td>SUPSI, HYP</td></tr>
<tr><td>STEP 4</td><td>After T:
Collect data related to the aggregated flexibilities</td><td>AEM, HYP, HIVE</td></tr>
<tr><td>STEP 5</td><td>After T:
Calculation of KPI(T)</td><td>SUPSI</td></tr>
</table>

KPI.CH.06

<table>
<tr><td>KPI ID</td><td>KPI.CH.06</td></tr>
<tr><td>KPI Name</td><td>Max flexibility prediction accuracy</td></tr>
<tr><td>Associated strategic objective(s)</td><td>SO3. Ensure quality of supply in the context of increase of RES</td></tr>
<tr><td>Associated OPENTUNITY innovation</td><td>HEMS and BEMS Flexibility and DR optimization including initial settings algorithms.</td></tr>
<tr><td>Associated TC(s)</td><td>TC5.1.1, TC5.2.1</td></tr>
<tr><td>Responsible partner(s)</td><td>SUPSI</td></tr>
<tr><td>KPI Description</td><td>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.</td></tr>
<tr><td>KPI Formula</td><td>$$MAE = \frac{1}{T}\sum_{t\in T}\left|\frac{y(t)-x(t)}{x(t)}\right| \qquad \mathrm{T}:\{t: n_{activated} = n_{max}\}$$</td></tr>
<tr><td>Formula variables</td><td>• $y(t)$: observed profile of the flexible devices, during a flexibility call
• $x(t)$: 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
• n_{max}: maximum number of devices that can be activated
• MAE: mean absolute error over the flexibility call period</td></tr>
<tr><td>KPI Unit</td><td>-</td></tr>
<tr><td>Baseline</td><td>No baseline is available for this KPI, as the forecast service is being introduced for the first time</td></tr>
<tr><td>Target</td><td>0.3</td></tr>
<tr><td>Calculation steps</td><td>
<table>
<tr><th></th><th>Description</th><th>Responsible</th></tr>
<tr><td>STEP 1</td><td>Before time slot T:
Periodical collection of 15-minutes data related to the flexibilities available for the aggregation and to the meteorological situation</td><td>AEM, HYP, HIVE</td></tr>
<tr><td>STEP 2</td><td>Before T:
Performing of flexibility forecast and aggregation for time-slot T</td><td>SUPSI</td></tr>
<tr><td>STEP 3</td><td>@T:
Activation of flexibility</td><td>SUPSI, HYP</td></tr>
<tr><td>STEP 4</td><td>After T:
Collect data related to the aggregated flexibilities</td><td>AEM, HYP, HIVE</td></tr>
<tr><td>STEP 5</td><td>After T:
Calculation of KPI(T)</td><td>SUPSI</td></tr>
</table>
</td></tr>
</table>

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10.3.4 Spanish pilot KPIs

KPI.SP.01

KPI ID	KPI.SP.01
KPI Name	Topology detection MAPE
Associated strategic objective(s)	SO1. Decarbonization of EU society SO2. Citizen and stakeholder empowerment
Associated OPENTUNITY innovation	Topology identification and state estimation via machine learning
Associated TC(s)	TC4.1.1
Responsible partner(s)	ETRA
KPI Description	The aim of the KPI is to calculate the Mean Absolute Percentage Error (MAPE) to evaluate the accuracy of the Topology Identification module. In this scenario, MAPE is computed by taking the absolute difference between the estimated and actual topology of the system. This yields the average absolute discrepancy, expressed in percentage. A lower MAPE value indicates a more accurate Topology Identification. Conversely, a higher MAPE suggests that there is a greater level of discrepancy between the estimated and actual topology, which may be indicative of larger measurement errors or losses.
KPI Formula	$MAPE = \frac{1}{n}\sum_{i=1}^{n}\frac{\lvert y_i - \hat{y}_i\rvert}{\lvert y_i\rvert}$
Formula variables	• n is the total number of network loads and generators • y_i represents de actual state value a load and generator i • $\hat{y}_i$ represents the estimated state value at each load and generator i
KPI Unit	Percentage (%)
Baseline	0%
Target	<40%

Calculation steps		Description	Responsible
	STEP 1	Gather historical electrical information on loads and generators (P & Q) (D-X)	ANELL
	STEP 2	Build P & Q forecast models for each load and generator, considering exogenous variables (weather, calendar, etc.) (D-X)	ETRA
	STEP 3	Obtain real time values from selected buses (D)	ANELL
	STEP 4	Calculate grid state estimation for near-future using forecast model and available RT measurements (D)	ETRA
	STEP 5	After a while, obtain real time value from loads, generators and buses (D+1)	ANELL
	STEP 6	Compare obtained real time values with those calculated using state estimation. Calculate MAPE	ETRA
	STEP 7	Apply changes in topology and check if MAPE is enhanced. Present information about potential errors in the current topology based on this	ETRA

KPI.SP.02

KPI ID	KPI.SP.02
KPI Name	Fraud location detection error
Associated strategic objective(s)	SO2. Citizen and stakeholder empowerment SO3. Ensure quality of supply in a context of increase of RES
Associated OPENTUNITY innovation	Topology identification and state estimation via machine learning Advanced asset management
Associated TC(s)	TC4.2.1
Responsible partner(s)	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	$\Delta L = \lvert L_{real} - L_{predicted} \rvert$
Formula variables	• L_{real}: Real fraud location • $L_{predicted}$: Fraud location given by the algorithm
KPI Unit	m
Baseline	500-600 m
Target	100-200 m

Calculation steps

	Description	Responsible
STEP 1	Collect actual fraud locations during inspection from the same period	ANELL
STEP 2	Collect AMI data, SCADA data and test cycles of affected locations	ANELL
STEP 3	Perform Low voltage power flow calculation based on historical measurements (obtained by the test cycles and SCADA system, not estimated). Store the power losses and voltage drop observed on each line	ETRA
STEP 4	Analyze the evolution of power losses and voltage drops in every LV line. Those lines with suspicious behavior will be marked as potential fraud.	ETRA
STEP 5	Assess the correctness of the detections based on historical fraud records	ANELL

KPI.SP.03

KPI ID	KPI.SP.03
KPI Name	Fraud detection benefit
Associated strategic objective(s)	SO1. Decarbonization of EU society SO2. Citizen and stakeholder empowerment
Associated OPENTUNITY innovation	Topology identification and state estimation via machine learning Advanced asset management
Associated TC(s)	TC4.2.1
Responsible partner(s)	ETRA
KPI Description	This KPI measures the economic feasibility of deploying an NTL detection model by considering both the costs associated with inspection costs and the benefits achieved from preventing or addressing non-technical losses (True Positives benefits). This KPI only takes into account efficiency in detected frauds with current methods in order to be conservative. It does not take into account frauds that would not be detected (which are more costly) which would increase the interest of the developed technologies.
KPI Formula	$$Costs = \sum_{n=0}^{N_v} Inspection\ costs[€]$$
Formula variables	• Nv: Number of visits • Inspection [€]: Cost related to inspection of specific part of the electrical grid
KPI Unit	Percentage (%)
Baseline	Usually, when there is a suspicion of a fraud, it takes about 4 inspections to find the place. It also depends on the type of fraud. Frauds due to Marijuana plantation are 8 hours of work (+ involvement of the police) leading to a cost of 880€. For other frauds it is needed 4 hours that led to 440€. Normally it takes about 4 visits to validate the exact place of the fault, so in average it could take 1980€ per fraud. The detected frauds are then paid.
Target	The aim is to lower that number up to 1 visit leading to 660€ (66% reduction).
Calculation steps	(see steps below)

	Description	Responsible
STEP 1	Collect actual fraud locations during inspection from the same period	ANELL
STEP 2	Collect AMI data, SCADA data and test cycles of affected locations	ANELL
STEP 3	Perform Low voltage power flow calculation based on historical measurements (obtained by the test cycles and SCADA system, not estimated). Store the power losses and voltage drop observed on each line	ETRA
STEP 4	Analyze the evolution of power losses and voltage drops in every LV line. Those lines with suspicious behavior will be marked as potential fraud.	ETRA
STEP 5	Assess the correctness of the detections based on historical fraud records	ANELL
STEP 6	Calculate costs and benefits	ANELL

KPI.SP.04

KPI ID	KPI.SP.04
KPI Name	Fraud detection F1
Associated strategic objective(s)	SO1. Decarbonization of EU society SO2. Citizen and stakeholder empowerment
Associated OPENTUNITY innovation	Topology identification and state estimation via machine learning Advanced asset management
Associated TC(s)	TC4.2.1
Responsible partner(s)	ETRA
KPI Description	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. 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	$Precision = \frac{TP}{TP + FP}$ $Recall = \frac{TP}{TP + FN}$ $F1 = \frac{2\ x\ Precision\ \cdot\ Recall}{Precision + Recall}$
Formula variables	• TP: True Positives: number of identified, real frauds • FP: False Positives: number of identified, not real frauds • FN: False Negatives: number of real frauds not identified
KPI Unit	Percentage (%)
Baseline	30%
Target	60%
Calculation steps	

	Description	Responsible
STEP 1	Collect actual fraud locations during inspection from the same period	ANELL
STEP 2	Collect AMI data, SCADA data and test cycles of affected locations	ANELL
STEP 3	Perform low voltage power flow calculation based on historical measurements (obtained by the test cycles and SCADA system, not estimated). Store the power losses and voltage drop observed on each line	ETRA

	STEP 4	Analyze the evolution of power losses and voltage drops in every LV line. Those lines with suspicious behavior will be marked as potential fraud.	ETRA
	STEP 5	Assess the correctness of the detections based on historical fraud records	ANELL

KPI.SP.05

KPI ID	KPI.SP.05
KPI Name	Accuracy of fuse burn location
Associated strategic objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Associated OPENTUNITY innovation	Topology identification and state estimation via machine learning
Associated TC(s)	TC4.3.1
Responsible partner(s)	ANELL
KPI Description	This KPI will calculate the accuracy of the blown fuse detection algorithm. This algorithm is triggered when an outage is detected and aims at identifying blown fuses and pinpointing its exact location and phase through the monitoring of the voltage at end user level. The results of the blown fuse location will be compared with the actual results after the outage is solved. The accuracy of each individual detection will be calculated according to these criteria: 1) If blown fuse is correctly identified it accounts with 100% accuracy in the detection 2) If real blown fuse is not the predicted one, but they are separated by a single line section, it accounts with 90% accuracy 3) If real blown fuse is not the predicted one, but they are separated by two line sections, it accounts with 80% accuracy 4) If real blown fuse is not the predicted one, but they are separated by three line sections, it accounts with 70% accuracy 5) If any of the above is true, it accounts with 0% of accuracy
KPI Formula	$A = \frac{\sum acc_i}{Total\ number\ of\ blown\ fuses\ detected}$
Formula variables	• A: Accuracy • acc_i: Accuracy of detection of blown fuse i
KPI Unit	%
Baseline	N/A
Target	0,75
Calculation steps	

	Description	Responsible
STEP 1	Receive confirmation of an ongoing outage on a LV line.	ANELL
STEP 2	Receive real time measurements from LV network (test cycles and SCADA)	ANELL
STEP 3	Calculate potential blown fuse based on real time received data	ETRA
STEP 4	Confirm exact location of blown fuse. Calculate KPI	ANELL

KPI.SP.06

KPI ID	KPI.SP.06		
KPI Name	Reduction in outage recovery time after fuse burn		
Associated strategic objective(s)	SO3. Ensure quality of supply in a context of increase of RES		
Associated OPENTUNITY innovation	Topology identification and state estimation via machine learning		
Associated TC(s)	TC4.3.1		
Responsible partner(s)	ANELL		
KPI Description	This KPI will calculate the reduction in outage recovery time while facing a blown fuse. This algorithm is triggered when an outage is detected and aims at identifying blown fuses and pinpointing its exact location and phase through the monitoring of the voltage at end user level. The results of the blown fuse location will be compared with the actual results after the outage is solved. The outage recovery time will be calculated for the solution of the problem		
KPI Formula	$T_{reduction} = \frac{\sum T_{reduction-i}}{Total\ number\ of\ blown\ fuses\ detected}$		
Formula variables	• $T_{reduction}$: Total time reduction in outage recovery • $T_{reduction-i}$: O utage recovery time reduction for outage i •		
KPI Unit	minutes		
Baseline	90 minutes		
Target	25% better than baseline (67.5 minutes)		
Calculation steps		**Description**	**Responsible**
	STEP 1	Receive confirmation of an ongoing outage on a LV line.	ANELL
	STEP 2	Receive real time measurements from LV network (test cycles and SCADA).	ANELL
	STEP 3	Calculate potential blown fuse based on real time received data.	ETRA
	STEP 4	Confirm exact location of blown fuse. Calculate KPI.	ANELL

KPI.SP.07

KPI ID	KPI.SP.07
KPI Name	Critical points detection
Associated strategic objective(s)	SO1. Decarbonization of EU society SO2. Citizen and stakeholder empowerment
Associated OPENTUNITY innovation	Topology identification and state estimation via machine learning
Associated TC(s)	TC4.4.1
Responsible partner(s)	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. OPENTUNITY has a feature to identify for sections in the grid that might present problems given the current topology when a peak load situation (winter, summer, etc.) is observed. For the KPI calculation, these critical points will be obtained and will be compared with the historical power flow results. If a section is marked as critical and historical power flow results present traces of congestion at any historical moment, the detection is marked as correct, By 'traces of congestion' we mean a situation abnormally high in power flows. We are not expecting to see real congestion, as they are not frequent, but a threshold will be defined over the nominal capacity to mark a situation as 'trace of congestion'.
KPI Formula	$Precision = \frac{TP}{TP + FP}$ $Recall = \frac{TP}{TP + FN}$ $F1 = \frac{2\ x\ Precision\ x\ Recall}{Precision + Recall}$
Formula variables	• TP: Critical point (bus or line) detected and confirmed • FP: Critical point (bus or line) detected and NOT confirmed • FN: Critical point existing and not detected by the algorithm
KPI Unit	Percentage (%)
Baseline	0%
Target	80%

Calculation steps

	Description	Responsible
STEP 1	Provide detailed topology, including line section information	ANELL
STEP 2	Obtain peak scenario based on historical records	ANELL
STEP 3	Calculate critical points according to existing topology and peak scenario	ETRA
STEP 4	Compare critical points with historical power flow results. Calculate KPI.	ETRA

KPI.SP.08

KPI ID	KPI.SP.08		
KPI Name	Voltage volatility reduction		
Associated strategic objective(s)	SO3 Ensure quality of supply in a context of increase of RES		
Associated OPENTUNITY innovation	Flexibility market design and management		
Associated TC(s)	TC1.10.2		
Responsible partner(s)	ANELL		
KPI Description	This KPI evaluates the effectiveness of the participation of the distribution system operator to a local energy flexibility market for decreasing voltage volatility.		
KPI Formula	$$\Delta V = \sum_{n=1}^{N}\sum_{t=1}^{T}\frac{\lvert V_{n,t} - V_{nom}\rvert}{V_{nom}} \cdot 100\%$$		
Formula variables	• V_{nom}: Nominal voltage • $V_{n,t}$: Voltage at client level at flexibility activation n at time t • t: Time index ($t \in 1, \dots, T$) • n: Number of activations ($t \in 1, \dots, T$)		
KPI Unit	%		
Baseline	10%		
Target	5%		
Calculation steps		**Description**	**Responsible**
	STEP 1	Gather voltage data through DSO's AMI system and submetering data.	ANELL and IMPULSA
	STEP 2	Perform flexibility activation.	IMPULSA
	STEP 3	Analyse voltage fluctuation during and outside flexibility activations.	ANELL

KPI.SP.09

KPI ID	KPI.SP.09
KPI Name	Line congestion reduction
Associated strategic objective(s)	SO3 Ensure quality of supply in a context of increase of RES
Associated OPENTUNITY innovation	Flexibility market design and management
Associated TC(s)	TC1.10.2
Responsible partner(s)	ANELL
KPI Description	This KPI evaluates the effectiveness of the participation of the distribution system operator to a local energy flexibility market for decreasing line congestion.
KPI Formula	$$line\ saturation = \sum_{n=1}^{N}\sum_{t=1}^{T}\frac{I_{n,t}}{I_{max}} \cdot 100\%$$
Formula variables	• I_{max}: Maximum admissible current • $I_{n,t}$: Current at client level at flexibility activation n at time t • t: Time index ($t \in 1, \ldots, T$) • n: Number of activations ($n \in 1, \ldots$, N)
KPI Unit	%
Baseline	80%
Target	50%

Calculation steps

	Description	Responsible
STEP 1	Gather current data through DSO's AMI system	ANELL
STEP 2	Perform flexibility activation	IMPULSA
STEP 3	Analyse line capacity during and outside flexibility activations	ANELL

10.3.5 Slovenian pilot KPIs

KPI.SI.01

<table>
<tr><td>KPI ID</td><td>KPI.SI.01</td></tr>
<tr><td>KPI Name</td><td>EV fleet baseline forecast accuracy</td></tr>
<tr><td>Associated strategic objective(s)</td><td>SO3. Ensure quality of supply in a context of increased of RES</td></tr>
<tr><td>Associated OPENTUNITY innovation</td><td>Optimal selection of available flexibility</td></tr>
<tr><td>Associated TC(s)</td><td>TC3.1.1, TC3.1.2</td></tr>
<tr><td>Responsible partner(s)</td><td>AVANTCAR, UL, SETUP</td></tr>
<tr><td>KPI Description</td><td>This KPI measures the accuracy of baseline consumption forecasts for EV charging at both fleet and location level.
• At fleet level (whole portfolio), forecast accuracy is measured by the Weighted Mean Absolute Percentage Error (WMAPE).
• At location level (EV stations behind the same connection point, e.g. transformer), accuracy is measured by the Normalized Mean Absolute Error (nMAE), which is better suited for very low or zero consumption values.
This approach ensures that forecast errors are expressed consistently and fairly across locations of different sizes.</td></tr>
<tr><td>KPI Formula</td><td>1. Fleet-wide accuracy
$$WMAPE = \left(\frac{\sum_{t \epsilon T} |A_t - F_t|}{\sum_{t \epsilon T} |A_t|}\right) \times 100\%$$
2. Location-level accuracy
$$nMAE = \frac{1}{\mathrm{N}} \sum_{t=1}^{N} \frac{|A_t - F_t|}{P_{max}} \times 100\%$$</td></tr>
<tr><td>Formula variables</td><td>• A_t: Actual power value
• F_t: Forecasted power value
• T: Observed time period
• P_{max}: Maximum charging capacity at charging station location, defined as the sum of the maximum rater charging power of all charging stations at that location</td></tr>
<tr><td>KPI Unit</td><td>Percentage (%)</td></tr>
<tr><td>Baseline</td><td>Naïve D-1 persistence forecast</td></tr>
<tr><td>Target</td><td>• WMAPE (fleet): ≤30%
• nMAE (location): ≤50% (depending on site variability)</td></tr>
<tr><td>Calculation steps</td><td><table>
<tr><th></th><th>Description</th><th>Responsible</th></tr>
<tr><td>STEP 1</td><td>EV charging stations data continuously sent from AVANTCAR backend to SETUP platform</td><td>AVANTCAR, SETUP</td></tr>
<tr><td>STEP 2</td><td>Forecast models training</td><td>SETUP (fleet), UL (location specifics)</td></tr>
<tr><td>STEP 3</td><td>Forecast generation</td><td>SETUP (fleet), UL (location specifics)</td></tr>
<tr><td>STEP 4</td><td>KPI calculation</td><td>SETUP (fleet), UL (location specifics)</td></tr>
</table></td></tr>
</table>

KPI.SI.02

KPI ID	KPI.SI.02
KPI Name	HEMS fleet baseline forecast accuracy
Associated strategic objective(s)	SO3. Ensure quality of supply in a context of increased of RES
Associated OPENTUNITY innovation	Optimal selection of available flexibility
Associated TC(s)	TC3.2.1, TC3.2.2
Responsible partner(s)	Amibit, UL, SETUP
KPI Description	This KPI measures the accuracy of baseline consumption forecasts for households equipped with HEMS devices. The KPI is evaluated on two levels: • **Household level (per asset/channel)**: forecast accuracy is measured separately for each relevant channel such as PV generation, heat pump consumption, and grid exchange. • **Portfolio level (aggregated consumption)**: forecast accuracy is measured for the aggregated meter-level consumption of all connected HEMS households. The metric used is the Weighted Mean Absolute Percentage Error (WMAPE), which provides a balanced evaluation by normalizing errors relative to the sum of actual and forecast values, making it more robust across both consumption and generation channels.
KPI Formula	$WMAPE = \left(\frac{\sum_{t\epsilon T}\lvert A_t - F_t\rvert}{\sum_{t\epsilon T}\lvert A_t\rvert}\right) \times 100\%$
Formula variables	• A_t: Actual power value • F_t: Forecasted power value • T: Observed time period
KPI Unit	Percentage (%)
Baseline	Naïve D-1 persistence forecast
Target	• Portfolio level: 15-20% WMAPE • Household/individual asset: 30% WMAPE
Calculation steps	see below

	Description	Responsible
STEP 1	Data from Reduxi continuously sent to SETUP platform	Amibit, SETUP
STEP 2	Data export to UL (periodic)	SETUP, UL
STEP 3	Forecast models training	UL
STEP 4	Forecast generation	UL
STEP 5	KPI calculation	UL

KPI.SI.03

KPI ID	KPI.SI.03
KPI Name	Optimal selection algorithm latency/calculation time
Associated strategic objective(s)	SO3. Ensure quality of supply in the context of increase of RES
Associated OPENTUNITY innovation	Optimal selection of available flexibility
Associated TC(s)	TC3.3.1
Responsible partner(s)	UL, SETUP
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	$$L = TS_{Activation} - TS_{Response}$$
Formula variables	• 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.
KPI Unit	seconds
Baseline	30 s
Target	L <30 s

Calculation steps

	Description	Responsible
STEP 1	Scenario definition	SETUP, UL
STEP 2	Scenario simulation process	UL
STEP 3	KPI calculation	UL

KPI.SI.04

KPI ID	KPI.SI.04
KPI Name	Optimal selection algorithm bid satisfaction rate
Associated strategic objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Associated OPENTUNITY innovation	Optimal selection of available flexibility
Associated TC(s)	TC3.3.1
Responsible partner(s)	UL, SETUP
KPI Description	This KPI measures the percentage of requested flexibility (kW) that the optimal selection algorithm is able to satisfy in simulation scenarios. It provides a quantitative view of how well the algorithm performs against the demand and whether it can meet flexibility targets under given constraints.
KPI Formula	$F = \frac{\sum Flexibility\ fulfiled}{\sum Flexibility\ requested} \times 100\%$
Formula variables	• F: Bid fulfilment rate • $Flexibility\ fulfiled$: Total power (kW) committed by the algorithm for the scenario period • $Flexibility\ requested$: Total power (kW) requested across scenarios
KPI Unit	%
Baseline	Random allocation strategy (expected 70-80% fulfilment)
Target	100%

Calculation steps

	Description	Responsible
STEP 1	Scenario definition	SETUP, UL
STEP 2	Scenario simulation process	UL
STEP 3	KPI calculation	UL

KPI.SI.05

<table>
<tr><td>KPI ID</td><td colspan="3">KPI.SI.05</td></tr>
<tr><td>KPI Name</td><td colspan="3">Average expected revenue</td></tr>
<tr><td>Associated strategic objective(s)</td><td colspan="3">SO3. Ensure quality of supply in a context of increase of RES</td></tr>
<tr><td>Associated OPENTUNITY innovation</td><td colspan="3">Optimal selection of available flexibility</td></tr>
<tr><td>Associated TC(s)</td><td colspan="3">TC3.3.2</td></tr>
<tr><td>Responsible partner(s)</td><td colspan="3">UL, SETUP</td></tr>
<tr><td>KPI Description</td><td colspan="3">This KPI measures the profitability of the market selection logic by calculating the average expected daily revenue of the aggregator platform. It evaluates whether the algorithm consistently selects the most profitable market (e.g., DA, TSO) given flexibility forecasts and market price signals.</td></tr>
<tr><td>KPI Formula</td><td colspan="3">$$Average\ expected\ revenue = \frac{1}{D}\sum_{d=1}^{D} R_d$$
Where:
$$R_d = \sum_{t=1}^{T} P_{m,t} \cdot Q_t$$</td></tr>
<tr><td>Formula variables</td><td colspan="3">• D: number of days
• R_d: Expected revenue for day d (€)
• $P_{m,t}$: Market price for selected market m at interval t (€/MWh)
• Q_t: Flexibility quantity committed at interval t (€/MWh)</td></tr>
<tr><td>KPI Unit</td><td colspan="3">€/day</td></tr>
<tr><td>Baseline</td><td colspan="3">0 (no market participation)</td></tr>
<tr><td>Target</td><td colspan="3">/</td></tr>
<tr><td rowspan="4">Calculation steps</td><td></td><td>Description</td><td>Responsible</td></tr>
<tr><td>STEP 1</td><td>Data collection</td><td>SETUP</td></tr>
<tr><td>STEP 2</td><td>Market selection simulation (daily)</td><td>SETUP</td></tr>
<tr><td>STEP 3</td><td>KPI calculation</td><td>SETUP</td></tr>
</table>

KPI.SI.06

KPI ID	KPI.SI.06		
KPI Name	Charging cost savings		
Associated strategic objective(s)	SO3. Ensure quality of supply in a context of increase of RES		
Associated OPENTUNITY innovation	Optimal selection of available flexibility		
Associated TC(s)	TC3.3.3		
Responsible partner(s)	SETUP, AVANTCAR		
KPI Description	This KPI evaluates the percentage of electricity cost saved when using a cost-optimized charging schedule versus a baseline unoptimized scenario (e.g., immediate charging).		
KPI Formula	$S = \left(1 - \frac{Optimised\ cost}{Baseline\ cost}\right) \times 100\%$		
Formula variables	• S: cost savings (%) • $Optimised\ cost$: Total cost incurred under the smart schedule • $Baseline\ cost$: Estimated cost using default (non-optimized) charging		
KPI Unit	%		
Baseline	0 (immediate charging, no savings)		
Target	20%		
Calculation steps		**Description**	**Responsible**
	STEP 1	Data collection (EV charging data, DA price forecasts)	SETUP, AVANTCAR
	STEP 2	Optimized schedule generation	SETUP
	STEP 3	Schedule sent to AVANTCAR, applied to the charger station	AVANTCAR
	STEP 4	Monitoring of data, KPI calculation	SETUP

KPI.SI.07

KPI ID	KPI.SI.07
KPI Name	Tariff cost savings
Associated strategic objective(s)	SO3. Ensure quality of supply in a context of increase of RES
Associated OPENTUNITY innovation	Optimal selection of available flexibility
Associated TC(s)	TC3.3.4
Responsible partner(s)	UL, Amibit
KPI Description	This KPI quantifies the total electricity cost savings for a household using Reduxi's tariff optimization logic, compared to a simulated baseline consumption profile.
KPI Formula	$$T = \left(1 - \frac{Optimised\ cost}{Baseline\ cost}\right) \times 100\%$$
Formula variables	• T: tariff cost savings (%) • $Optimised\ cost$: Actual cost based on the optimized usage schedule • $Baseline\ cost$: Simulated cost with no optimization
KPI Unit	%
Baseline	0% (no optimization, current state)
Target	15%
Calculation steps	

	Description	Responsible
STEP 1	Data collection	Amibit
STEP 2	Optimized schedule simulation	Amibit
STEP 3	KPI calculation	Amibit

KPI.SI.08

<table>
<tr><td>KPI ID</td><td colspan="3">KPI.SI.08</td></tr>
<tr><td>KPI Name</td><td colspan="3">Data completeness rate</td></tr>
<tr><td>Associated strategic objective(s)</td><td colspan="3">SO3. Ensure quality of supply in a context of increase of RES</td></tr>
<tr><td>Associated OPENTUNITY innovation</td><td colspan="3">Optimal selection of available flexibility</td></tr>
<tr><td>Associated TC(s)</td><td colspan="3">TC3.1.3, TC3.2.3</td></tr>
<tr><td>Responsible partner(s)</td><td colspan="3">UL, SETUP, Amibit, AVANTCAR</td></tr>
<tr><td>KPI Description</td><td colspan="3">This KPI measures the percentage of expected data points successfully received from each EV or HEMS device/channel. It provides an overview of data transmission reliability.</td></tr>
<tr><td>KPI Formula</td><td colspan="3">$$DCR = \frac{N_{received}}{N_{expected}} \times 100\%$$</td></tr>
<tr><td>Formula variables</td><td colspan="3">• DCR: data completeness rate (%)
• $N_{received}$: Number of data points received
• $N_{expected}$: Number of data points expected over the period</td></tr>
<tr><td>KPI Unit</td><td colspan="3">%</td></tr>
<tr><td>Baseline</td><td colspan="3">Minimum acceptable data completeness set at 85%.</td></tr>
<tr><td>Target</td><td colspan="3">90%</td></tr>
<tr><td rowspan="4">Calculation steps</td><td></td><td>Description</td><td>Responsible</td></tr>
<tr><td>STEP 1</td><td>Data being sent from AVANTCAR and Amibit, collected in SETUP PLATFORM</td><td>Amibit, AVANTCAR, SETUP</td></tr>
<tr><td>STEP 2</td><td>Continuous check of data completeness</td><td>SETUP</td></tr>
<tr><td>STEP 3</td><td>KPI calculation</td><td>SETUP, UL</td></tr>
</table>

10.3.6 Separate, cross-platform KPIs

New KPI ID	Old KPI ID	Title	Action	Comment
KPI.PP.01	-	QR code functionality rate	Added	
KPI.PP.02	-	Completeness score	Added	
KPI.DSP.01	-	New participant onboarding time	Added	This KPI was not included in D2.1 as the initial project architecture was based on blockchain, and onboarding was not yet defined as a measurable process within the Federated Data Space

KPI.PP.01

KPI ID	KPI.PP.01		
KPI Name	QR code functionality rate		
Associated strategic objective(s)	SO1. Decarbonization of EU society SO2. Citizen and stakeholder empowerment		
Associated OPENTUNITY innovation	Plug and play recognition for flexibility devices		
Associated TC(s)	TC.PP.01		
Responsible partner(s)	BSA		
KPI Description	Measures the reliability of the plug-and-play onboarding flow. It's the percentage of QR codes (OPENTUNITY-QR or DPP-QR) that, when scanned on a device or system during HEMS/BEMS setup or NILM estimation, successfully returns valid device or system specifications.		
KPI Formula	$QR\ Code\ Functionality\ Rate = \frac{\text{Successful QR triggered retrievals}}{Total\ QR\ codes\ tested} \cdot 100$		
Formula variables	• $Successful\ QR\ triggered\ retrievals$: Number of QR scans (OT-QR or DPP) for which an OPENTUNITY Partner explicitly confirmed end-to-end success by posting an acknowledgment after parsing the JSON asset data. This shows that the whole plug-and-play flow worked, not just the HTTP delivery. • $Total\ QR\ codes\ tested$: Total number of QR scans attempted (OT-QR or DPP), regardless of whether the delivery succeeded or the OPENTUNITY partner returned an acknowledgment. This is the baseline for measuring the reliability of the entire onboarding process.		
KPI Unit	% (percentage).		
Baseline	0%		
Target	≥ 90% functionality across all pilot QR scans		
Calculation steps		**Description**	**Responsible**
	STEP 1	Web-app generates random ID (RID) when a QR is scanned	BSA
	STEP 2	QR attempt is logged when the web-app serves JSON (success/fail)	BSA
	STEP 3	OPENTUNITY partner parses JSON and posts back an ACK with the same RID	BSA

	STEP 4	Web-app marks ACK=True or False, then computes and displays the KPI	BSA

KPI.PP.02

KPI ID	KPI.PP.02
KPI Name	Completeness score
Associated strategic objective(s)	SO1. Decarbonization of EU society SO2. Citizen and stakeholder empowerment
Associated OPENTUNITY innovation	Plug and play recognition for flexibility devices.
Associated TC(s)	TC.PP.01
Responsible partner(s)	BSA
KPI Description	Quantifies the richness of asset data (JSON) provided by Economic Operators (EO), going beyond mandatory fields by weighting essential, recommended, and optional specifications during flexible asset registration.
KPI Formula	$Completeness\ Score = \frac{\Sigma\ (weights\ of\ filled\ fields)}{\Sigma\ (weights\ of\ all\ fields\ considered)} \cdot 100$
Formula variables	• $\Sigma\ (weights\ of\ filled\ fields)$: the sum of weight factors of all asset-data fields that the EO has actually filled in (provided) for that asset (mandatory, recommended, or optional) • $\Sigma\ (weights\ of\ all\ fields\ considered)$: the total sum of weight factors of all fields relevant to that asset's class (e.g., asset core + BESS specs for a battery system) • $Completeness\ Score$: the ratio of the two sums, multiplied by 100, giving a percentage that reflects how complete the asset's data is for integration
KPI Unit	% (percentage)
Baseline	0%
Target	≥ 70% completeness across all pilot asset registrations

Calculation steps

	Description	Responsible
STEP 1	Web-app Identifies applicable data fields for an asset's class, during its registration.	BSA
STEP 2	The application checks values "provided" for the registered asset in its database against those data fields. It treats a field as "provided" only if it has a non-null, non-empty value.	BSA
STEP 3	The application sums weights of "provided" fields and weights of all applicable fields.	BSA
STEP 4	The application computes and displays the KPI.	BSA

KPI.DSP.01

<table>
<tr><td>KPI ID</td><td colspan="3">KPI.DSP.01</td></tr>
<tr><td>KPI Name</td><td colspan="3">New participant onboarding time</td></tr>
<tr><td>Associated strategic objective(s)</td><td colspan="3">SO1. Decarbonization of EU society
SO2. Citizen and stakeholder empowerment</td></tr>
<tr><td>Associated OPENTUNITY innovation</td><td colspan="3">Federated Data Exchange Innovation Architecture</td></tr>
<tr><td>Associated TC(s)</td><td colspan="3">TC.DSP.01, TC.DSP.02</td></tr>
<tr><td>Responsible partner(s)</td><td colspan="3">QUE</td></tr>
<tr><td>KPI Description</td><td colspan="3">Measures the time required for a new participant to be successfully onboarded into the OPENTUNITY Federated Data Space, starting from registration in the Onboarding Portal to the deployment of the participant template and activation in the system.</td></tr>
<tr><td>KPI Formula</td><td colspan="3">$Onboarding\ Time\ (minutes) = T_{completion} - T_{registration}$</td></tr>
<tr><td>Formula variables</td><td colspan="3">• $T_{registration}$: Timestamp when participant submits registration in Onboarding
• $T_{completion}$: Timestamp when onboarding is finalized</td></tr>
<tr><td>KPI Unit</td><td colspan="3">Minutes</td></tr>
<tr><td>Baseline</td><td colspan="3">>= 1 day</td></tr>
<tr><td>Target</td><td colspan="3"><= 120 minutes</td></tr>
<tr><td rowspan="3">Calculation steps</td><td></td><td>Description</td><td>Responsible</td></tr>
<tr><td>STEP 1</td><td>Record registration submission timestamp in Onboarding UI</td><td>QUE</td></tr>
<tr><td>STEP 2</td><td>Record onboarding completion timestamp</td><td>QUE</td></tr>
</table>