Cost-effective and replicable RES-integrated electrified heating and cooling systems for improved energy efficiency and demand response.

D3.2 - Holistic SEEDS Evaluation Framework

WP3, Task 3.3 Use Case Scenarios and KPIs definition for Automation Systems

April 2025

Author(s): Tsompanidou Eleni (CERTH), Iakovos Michailidis (CERTH), Achilleas Andronikos (CERTH), George Karatzinis (CERTH), Kyriaki Fanaridou (CERTH), Apostolos Gkountas (PTHERM), Evangelia Rigati (RENEL), Nikolaos Rapkos (RENEL), Pantelis Botsaris (DUTh), Lieve Helsen (KUL), Louis Hermans (KUL), Filip Jorissen (BWS), Ann Bruggeman (Sweco), Robin Haesen (SWECO), Arno Marechal (Sweco), Marie-Louise Krogh (CDK), Shahab Tohidi (DTU - Compute), Erik Gramc (Petrol), Bernard Ženko (JSI), Profigram (Peter Grabner), Fair C (György László), ÉMI (Károly Matolcsy)

DISCLAIMER

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

COPYRIGHT NOTICE

DELIVERABLE INFORMATION

Grant agreement	101138211
Project title	Cost-effective and replicable RES-integrated electrified heating and cooling systems for improved energy efficiency and demand response.
Project acronym	SEEDS
Project coordinator	Danmarks Tekniske Universitet - DTU
Related work package	WP 3
Related task(s)	Task 3.3 - Use Case Scenarios and KPIs definition for Automation Systems.
Lead organisation	CERTH
Contributing partner(s)	PETROL, JSI, DTU - Compute, CDK, Sweco, KUL, BWS, SMENS, ÉMI, FairC, DUTH, RENEL
Due date	30.04.25
Submission date	07.05.25
Dissemination level	PU

Co-funded by
the European Union

REVISION AND HISTORY CHART

Version	Date	Editors	Description
V0.1	01.11.24	CERTH (Eleni Tsompanidou)	First ToC
V0.2	04.02.25	KUL (Lieve Helsen , Louis Hermans, BWS (Filip Jorissen), SWECO (Ann Bruggeman, Arno Marechal)	Addition of Belgium pilot use cases
V0.2	04.02.25	CDK (Marie-Louise Krogh), DTU - Compute (Shahab Tohidi)	Addition of Danish pilot use cases
V0.2	04.02.25	Petrol (Erik Gramc), JSI(Bernard Ženko)	Addition of Slovenian pilot use cases
V0.2	04.02.25	DUTh (Pantelis Botsaris), CERTH (Tsompanidou Eleni, Iakovos Michailidis, Achilleas Andronikos, George Karatzinis, Kyriaki Fanaridou), PTHERM (Apostolos Gkountas), RENEL (Nikolaos Rapkos, Evangelia Rigati),	Addition of Greek pilot use cases
V0.3	05.02.25	CERTH (Achilleas Andronikos)	Addition of KPIs related to automation systems and platforms
V0.3	05.02.25	RENEL (Evangelia Rigati)	Addition of KPIs related to electrification systems
V0.3	05.02.25	KUL (Louis Hermans)	Addition of KPIs related to smart building services
V0.3	05.02.25	DTU - Compute (Shahab Tohibi)	Addition of KPIs related to smart grid services
V0.4	01.04.25	CERTH (Tsompanidou Eleni)	Review all the use cases Full draft ready for peer review before official review
V06	10.04.25	BWS (Filip Jorissen), Petrol (Erik Gramc), DTU - Compute (Shahab Tohibi)	Additional info added
V0.7	16.04.25	SWECO (Natan Vandeginste), INNOVATIO (Konstantinos Arvanitis)	Official review
V0.75	29.04.25	CERTH (Tsompanidou Eleni), Károly Matolcsy (ÉMI)	Address the reviewer's comments Addition of Hungarian pilot use cases
V0.80	06.05.25	SWECO (Natan Vandeginste)	Oficial review
V1	07.05.25	CERTH (Tsompanidou Eleni)	Final Deliverable

EXECUTIVE SUMMARY

This document outlines the holistic technical evaluation framework developed for the SEEDS project, incorporating contributions from all technical work packages (WP2–WP5). It focuses on defining use cases, test scenarios, and key performance indicators (KPIs) to guide the evaluation of the project's innovative systems and platforms. Specifically:

- **WP2** focuses on "electrification systems."
- **WP3** addresses "envisioned automation systems and platforms"
- **WP4** examines "smart building services."
- **WP5** explores "smart grid services."

Work package/task leaders, pilot leaders, and technology providers collaborated to define use cases for all SEEDS pilot sites (Belgium, Denmark, Greece, Hungary, and Slovenia). The use case methodology follows the standardized IEC 62559 framework, offering a structured approach to describe interactions between actors (users) and systems. A total of 19 use cases have been defined: 4 for the Belgian pilot, 3 for the Danish pilot, 4 for the Hungarian pilot, 6 for the Greek pilot, and 2 for the Slovenian pilot.

Beyond the use case definitions, this deliverable includes the definition of KPIs. These KPIs are designed to evaluate the progress and performance of pilot activities within each technical work package (WP2-WP5). The document specifies the KPIs relevant to each pilot site and details the monitoring levels required for systematic evaluation.

By consolidating the planned outcomes and evaluation strategies from WP2 to WP5, this deliverable establishes a foundational framework for assessing the impact and effectiveness of the SEEDS project innovations once implemented.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Abbreviation table

Abbreviation	Full Form
API	Application Programming Interface
BE	Belgian
DK	Danish
GR	Greek
HU	Hungarian
IoT	Internet of things
KPI	Key Performance Indicator
MPC	Model Predictive Control
SL	Slovenian
UC	Use Case
WP	Work Package

Co-funded by
the European Union

1. INTRODUCTION

1.1. AIMS AND OBJECTIVES

The primary aim of Deliverable D3.2 – Holistic SEEDS Evaluation Framework is to develop a comprehensive evaluation framework that consolidates the outcomes from T3.3 – Use Case Scenarios and KPIs Definition for Automation Systems and integrates relevant contributions from all technical work packages (WP2–WP5). This deliverable ensures a structured and cohesive approach to assessing the progress, effectiveness, and impact of the technical innovations implemented within the SEEDS project. The main objectives of the task are to:

- Define use case scenarios using the IEC 62559 framework, providing structured descriptions of interactions between users and systems.
- Develop KPIs to evaluate progress and performance across all pilot sites, specifying their relevance and monitoring levels for each location.
- Consolidate methodologies and contributions from WP2 (Electrification), WP3 (Automation Systems), WP4 (Smart Building Services), and WP5 (Smart Grid Services) into a cohesive evaluation strategy.

1.2. RELATION TO OTHER ACTIVITIES IN THE PROJECT

Deliverable D3.2, “Holistic SEEDS Evaluation Framework,” is closely linked to Task T3.2, “Technical Architecture and Specifications Definition,” which establishes the technical specifications used in T3.3 to define the corresponding use cases and KPIs.

As a consolidated evaluation framework, D3.2 incorporates contributions from all technical WPs, establishing strong connections not only with WP3, “Enabling Automation and Smartness through Secure and Interoperable Middleware Data Platforms and IoT Devices,” but also with other WPs. Specifically, use cases and KPIs from WP2, “Iterative Design of Component and Integrated Systems for Improved Energy Efficiency,” WP4, “Integrated Building System Operation Optimization for Energy Efficiency,” and WP5, “Deploying Energy Flexibility to Enhance Electricity Grid Stability,” are integral to D3.2.

Furthermore, Task T3.3 is directly related to T2.6, “Smart Electrification Systems Performance Assessment,” T4.3, “Deployment, Demonstration, and Evaluation of the Three MPC Approaches in the Three Pilots,” and T5.6, “Evaluation of Flexibility Services.” These tasks focus on assessing electrification systems, Model Predictive Control (MPC) performance, and energy flexibility services, respectively. T3.3 provides the evaluation criteria necessary to measure performance within these tasks.

Co-funded by the European Union

Moreover, the KPIs developed in T3.3 not only support internal technical evaluation but also contribute to external communication efforts. In WP7, selected KPIs will be used in visual storytelling (T7.4) to demonstrate the performance, efficiency, and benefits of the SEEDS solutions, helping decision-makers assess and replicate thermal system electrification and energy optimization projects. In WP8, KPIs will probably be used to support dissemination activities, helping to highlight the value and impact of SEEDS innovations to external audiences.

Thus, D3.2 and the activities in T3.3 are key to both the technical evaluation and the broader impact and replication goals of the project.

Co-funded by
the European Union

1.3. REPORT STRUCTURE

This deliverable includes four main chapters, a conclusion chapter, and six annexes. Specifically, Chapter 1 introduces the deliverable, outlining its aims, objectives, and its relation to other activities within the SEEDS project. Chapter 2 explains the methodology used to define the use cases and KPIs. Chapters 3 and 4 describe the use cases for all pilot sites and the KPIs that will be used to assess the entire SEEDS project, respectively.

The conclusion chapter summarizes the key points, while the six annexes provide additional details. The first five annexes include information on which KPIs apply to each pilot site, their respective monitoring levels, and the data providers responsible for supplying the necessary data. The final annex contains the template used for the definition of the use cases.

2. METHODOLOGY

The evaluation of SEEDS requires a structured methodology to assess its effectiveness in achieving the goals of decarbonizing buildings and enhancing energy efficiency and flexibility. This assessment is crucial not only for measuring the project's impact but also for ensuring that the tailored solutions deployed in diverse real-world contexts are scalable, replicable, and aligned with SEEDS' overarching objectives.

The project focuses on three key pillars: cost efficiency, system integration, and replicability, which guide the development of Key Performance Indicators (KPIs) to track progress in these areas. The project's work spans four main categories: electrification systems, automation systems, smart building services, and smart grid services. KPIs are vital tools for monitoring the effectiveness of SEEDS' solutions, enabling stakeholders to measure advancements in energy efficiency, grid stability, and operational cost reduction.

Through T3.3, partners from all pilot sites, along with technical partners and WP/Task leaders, collaborated to define the KPIs and use cases. CERTH, as the task leader, proposed the template for use cases and KPIs, which were finalized through discussions with all partners involved in T3.3. RENEL, KUL, and DTU - Compute were responsible for the collection of use cases and definition of KPIs within WP2 ("Iterative Design of Components and Integrated Systems for Improved Energy Efficiency"), WP4 ("Integrated Building System Operation Optimization for Energy Efficiency and Flexibility"), and WP5 ("Deploying Energy Flexibility to Enhance Electricity Grid Stability"). CERTH, in turn, was responsible for the use cases and KPIs under WP3 ("Enabling Automation and Smartness Through Secure and Interoperable Middleware Data Platforms and IoT Devices"). Pilot leaders and technical providers filled in the use case templates and provided information on whether the KPIs are applicable to their pilot sites, the data sources, and the corresponding monitoring levels.

Meetings were organized to present the use case templates and methodology, and private meetings were held for specific pilots.

2.1. USE CASE METHODOLOGY

The SEEDS Use Cases were created using a well-established methodology commonly applied in other European projects focusing on Smart Grid solutions. This methodology is based on the IEC 62559[1] standard. The pre-existing standard templates for Use Case descriptions were adapted to meet the specific requirements of SEEDS. Below are the key definitions used in this methodology:

- **Use Case**: A detailed description of how users (actors) interact with a system to achieve a specific goal. It outlines the steps involved, the conditions under which the interaction occurs, and the expected outcomes.

[1] https://www.sis.se/api/document/preview/8013841/

Co-funded by
the European Union

- **Actors**:
  - **Primary Actors**: The main users who initiate and benefit from the use case (e.g., building managers, end-users).
  - **Secondary Actors**: Entities that support or are affected by the use case but are not the main initiators (e.g., maintenance personnel, energy providers).
- **System**: The technology or platform that facilitates the interactions described in the use case. This can include hardware, software, and integrated solutions that perform specific functions to achieve the use case's objectives.

The use case template includes the following information: a description of the use case, its scope and objectives, limitations, pilot sites involved, assets, technical details such as assets and actors, diagrams, use case scenarios, and the steps involved.
The template used for the use cases can be found in Annex 6 Use case Template.
The final use cases chosen by the pilots are listed in the table below.

Table 1 SEEDS Use Cases

Title of UC	Pilot Involved	Partners responsible
Capturing of telemetry data	Belgium	BWS
Model predictive control using calibrated models	Belgium	BWS, KUL
Iterative HVAC design to propagate the electrification of thermal energy demand	Belgium	KUL, SWECO
Improving thermal system designs by using integrated optimal design methodologies	Belgium	BWS, KUL, SWECO,
Capturing of telemetry data	Danish	CDK
Model predictive control using Grey-Box model for the Danish Pilot	Danish	DTU - Compute
Flexibility function integrated flexibility services	Danish	DTU - Compute
Electrification of thermal energy demand	Greek	CERTH, PTHERM
Minimization of Life Cycle Environmental Impact through Circular Design Principles	Greek	RENEL, DUTH
Capturing of telemetry data	Greek	CERTH
Active control of electrification systems	Greek	RENEL, CERTH
Predictive Maintenance of Heat Pump and PV Systems	Greek	RENEL, CERTH
Participation in Demand Response Schemes	Greek	CERTH
Setting up and testing the system to be deployed	Hungarian	Profigram, Fair C, ÉMI
Control system design and construction	Hungarian	Profigram, Fair C, ÉMI
Integration of Flexibility into MPC and Interaction with DSO	Hungarian	Profigram
Integration of Electric Vehicle Charger into the MPC Framework	Hungarian	Profigram
Capturing of telemetry data	Slovenian	PETROL
Providing flexibility services	Slovenian	JSI

Co-funded by
the European Union

2.2. KPIS COLLECTION

As mentioned in the introduction of chapter 2 (Methodology), KPIs for electrification systems, automation systems, smart building services, and smart grid services were defined by RENEL, CERTH, KUL, and DTU - Compute, respectively. Pilot leaders and technical providers then selected the KPIs relevant to their specific pilot sites.
Each KPI is identified by its KPI card, which includes essential information such as the KPI description, formulas, suggested data sources, units of measurement, and more. Figure 1 displays the generic SEEDS KPI card template.

<table>
<tr><th colspan="6">PART A: KPI Profile</th></tr>
<tr><td>KPI Name:</td><td></td><td>Type:</td><td>CORE</td><td colspan="2">SUPPORTING</td></tr>
<tr><td>Description:</td><td colspan="5"></td></tr>
<tr><th colspan="6">PART B: KPI Calculation</th></tr>
<tr><td>Unit:</td><td></td><td colspan="2">Baseline Estimations Required:</td><td>YES</td><td>NO</td></tr>
<tr><td>KPI Formula:</td><td colspan="5"></td></tr>
<tr><td>Recommended Data Sources:</td><td colspan="5"></td></tr>
<tr><td>Recommended time interval of KPI reporting:</td><td></td><td colspan="3">Recommended time interval for data monitoring:</td><td></td></tr>
</table>

Figure 1 SEEDS KPI card template

Co-funded by
the European Union

3. USE CASES

3.1. USE CASES OF BELGIAN PILOT (BE)

3.1.1. *UC – BE 1: Capturing of telemetry data*

Description of the Use Case

Use case Identification		
ID	**Title**	**Domain**
BE1	Capturing of telemetry data	Smart Buildings, Energy Management, Building Automation

Version Management			
Version No	**Date**	**Name of authors**	**Changes**
01	18.12.24	CERTH (Tsompanidou Eleni)	Initial draft outlining the main idea and scope of the Use case
02	19.02.25	Builtwins (Filip Jorissen)	Complete Use Case Description (including objectives, steps)
03	01.04.25	CERTH	Review for validation
04	05.04.25	Builtwins	Final version

Classification Information	
Pilot Involved	Belgium
Relation to Other Use Cases	– UC – BE 2: Model predictive control using calibrated model – UC – BE 3: Iterative HVAC design to propagate the electrification of thermal energy demand – UC – BE 4: Improving thermal system designs by using integrated optimal design methodologies
Related Innovative SEEDS solutions	White-box MPC calibration method
Assets of the UC	- Graphite Database (centralized storage). - API (secure data retrieval). - Grafana Visualization (real-time monitoring).

Co-funded by the European Union

	- Data Cleaning Algorithms (handling missing or erroneous data). - Secure Communication Protocols (HTTPS, token authentication).

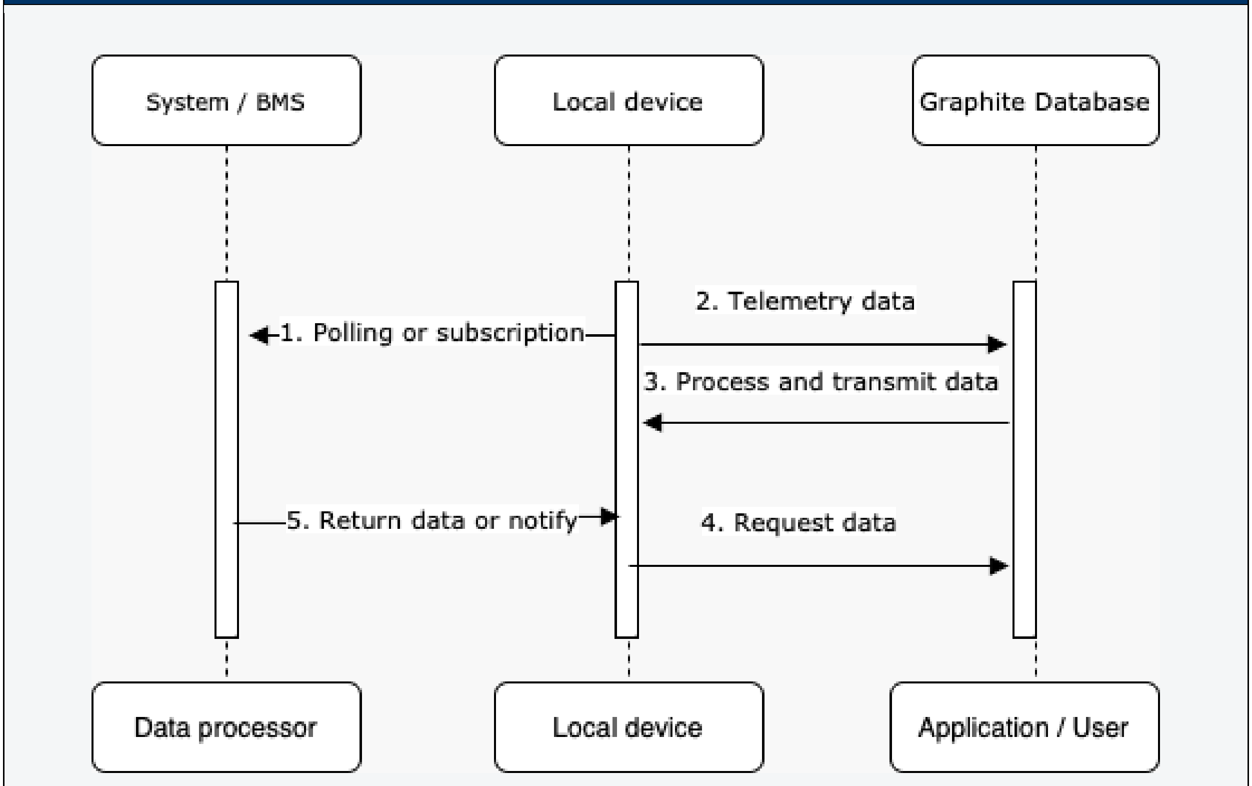
Scope and Objectives of Use Case	
Scope of the use case	This use case focuses on capturing and managing telemetry data from various systems in the Belgian pilot, enabling seamless integration into a centralized data management platform. The process involves: - Identifying and integrating telemetry data sources. - Ensuring data quality and consistency. - Providing secure and structured access for analytics and operational optimization
Objectives of the use case	1. Identify and integrate telemetry data sources from IoT sensors, energy meters, HVAC systems, and BMS (Building Management Systems). 2. Establish a secure and reliable data pipeline using standard protocols (BACnet, Modbus, M-bus). 3. Implement data validation techniques to ensure data integrity for analytical applications. 4. Enable stakeholder access via an API and visualization tools (Grafana). 5. Maintain continuous data flow for uninterrupted operations and long-term storage.
Limitations & Assumptions	- Telemetry systems are assumed to be operational and accessible at all times. - Integration with existing BMS protocols (BACnet, Modbus, M-bus) is assumed to be technically feasible. - Data quality checks depend on the specific analytical use case. - Network connectivity is assumed to be stable for real-time data transmission.

Narrative of Use Case	
Short Description	This use case describes the automated capture, storage, and utilization of telemetry data from multiple sources. The collected data is stored in a centralized Graphite database and made accessible for real-time analysis, optimization, and decision-making.
Complete Description	Telemetry data from various building systems—such as room temperature sensors, energy meters, HVAC systems, and IoT devices—is collected, processed, and stored in a Graphite database. The collection occurs via BACnet,

	Modbus, and M-bus protocols, either through polling (reading values at intervals) or subscription-based updates (triggered when a threshold is exceeded). Minimal processing ensures data integrity, with read errors stored as 'none' values instead of being omitted. Data is transmitted securely over HTTPS and stored at equidistant intervals: every minute for the first 100 days, then every 15 minutes for up to six years. Older data is aggregated using methods such as averaging to optimize storage without compromising analytical value. Data can be accessed via a token-secured API (providing JSON-formatted data for automation) or through Grafana, which enables users to visualize, analyze, and export data in CSV format. Functions like unit scaling, resampling, and interpolation can be applied depending on the use case. Processing methods vary based on application needs: real-time monitoring may interpolate missing data, calibration models may ignore it, and Model Predictive Control (MPC) can replace it with the last known value. This flexibility ensures reliable data-driven decision-making for analytics, system calibration, and optimization

Diagrams of the UC

Sequence diagram of the use case



Technical Details of the UC

Actors			
Actor Name	**Actor Type**	**Actor Description**	**Further information specific to this Use Case**
Data Collection Device	System	Collects telemetry data from sensors and devices.	Uses BACnet, Modbus, or M-bus protocols.
Central Database	System	Stores raw and processed telemetry data.	Graphite database with secure HTTPS transmission.
API Service	System	Provides secure access to stored telemetry data.	Uses HTTPS with token authentication.
Visualization Platform	System	Enables users to view and analyze data.	Grafana for plots, functions, and CSV downloads.
Building Management System (BMS)	System	Manages building automation and sensor data.	Provides real-time telemetry data for analytics.
System Operator	Human	Monitors and analyzes telemetry data.	Uses Grafana for visualization and CSV export.
Automated Control Algorithm	System	Uses telemetry data for optimization (e.g., MPC).	Processes data via API for real-time adjustments.

Co-funded by the European Union

Step-by-step analysis of use case

Overview of scenarios

Scenario Conditions						
No	**Scenario title**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-Condition**
S01	Data Collection & Storage	Collection of telemetry data from sensors and storing it in the database.	Data Collection Device	New sensor reading is available.	Sensors are operational.	Data is stored in Graphite DB.
S02	Data Access via API	External system retrieves data for analysis.	API Service	API request from external system.	Data is available in DB.	Data is provided in JSON format.
S03	Data Visualization	Users view and analyze data using Grafana.	System Operator	User accesses Grafana interface.	Data is stored in DB.	Data visualization is displayed.
S04	Automated Data Processing	System processes telemetry data for analysis or control.	Automated Control Algorithm	Data retrieval request is triggered.	Data available in DB and API.	Processed data is used for optimization.

Steps per scenario

Scenario Name		**Data Collection & Storage**						
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
1	Sensor Reading	Data Collection	Sensor collects telemetry data.	BMS	Data Collection Device	BMS	Sensor Data ID	Data must be collected at least once per minute

2	Data Transmission	Secure Transmission	Data is sent to the central database.	HTTPS	Data Collection Device	Central Database	Encrypted Data ID	Data must be transmitted using HTTPS protocol with encryption.
3	Data Storage	Data Logging	Data is stored at equidistant intervals.	Graphite DB	Central Database	Database	Time-Series Data ID	Data must be stored in a time-series format, updated every minute initially and every 15 minutes after 100 days.

Scenario Name	**Data Access via API**							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
1	API Request	Data Retrieval	External system sends an API request.	API	External System	API Service	Request Data ID	The system must provide an API endpoint that allows external systems to request data.
2	Data Processing	Query Execution	API processes request and retrieves data.	API	API Service	Central Database	Query Response ID	The API must handle and execute data queries efficiently, ensuring correct retrieval from the database.

3	Data Delivery	Response Transmission	API sends data in JSON format.	API	API Service	External System	JSON Data ID	The API must respond with the requested data in JSON format with token-based authentication.

Scenario Name	**Data Visualization**							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
1	User Login	Authentication	User logs into Grafana platform.	Grafana	System Operator	Visualization Platform	Login Credentials	The system must authenticate users securely before allowing access to the platform.
2	Data Query	Fetch Data	Grafana queries the central database for data.	Grafana	Visualization Platform	Central Database	Query Data ID	Data retrieval from the database must support efficient query handling and filtering.
3	Data Display	Visualization	Data is displayed as plots or CSV files.	Grafana	Visualization Platform	System Operator	Displayed Data ID	The platform must be capable of visualizing data in charts or exporting it as CSV files.

Co-funded by
the European Union

Scenario Name		Automated Data Processing						
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
1	Data Request	Fetch Data	Algorithm requests telemetry data.	API	Automated Control Algorithm	API Service	Request Data ID	The algorithm must be able to request telemetry data from the API for real-time processing.
2	Data Processing	Algorithm Execution	Data is processed based on application needs.	Algorithm	Automated Control Algorithm	System Operator	Processed Data ID	The system must execute algorithms that analyze data in real-time for optimization purposes.
3	Data Output	Optimization Control	Processed data is used for optimization control.	Algorithm	Automated Control Algorithm	BMS	Control Data ID	The system must ensure that processed data is sent to the BMS for control actions (e.g., HVAC adjustments).

Co-funded by
the European Union

3.1.2. UC – BE 2: Model predictive control using calibrated models

Description of the Use Case

Use case Identification		
ID	**Title**	**Domain**
BE2	Model predictive control using calibrated models	Building Automation and Energy Management

Version Management			
Version No	**Date**	**Name of authors**	**Changes**
01	29.08.2024	Filip Jorissen (BWS)	First proposal of use case
02	26.11.2024	Louis Hermans (KUL)	Additional Information Added
03	19.02.2025	Filip Jorissen	General review and feedback
04	02.04.2025	Tsompanidou Eleni (CERTH)	Review
05	05.04.2025	Filip Jorissen	Final use case

Classification Information	
Pilot Involved	Belgium
Relation to Other Use Cases	UC – BE 1: Capturing of telemetry data
Related Innovative SEEDS solutions	Calibrated white-box MPC
Assets of the UC	Heat pumps, IoT sensors, Mathematical model of the building

Scope and Objectives of Use Case	
Scope of the use case	The scope of the use case relates to Model Predictive Control (MPC). Builtwins' MPC uses a detailed physics-based model to control the HVAC devices within a building. Due to its physics-based nature, the model is built using as-built file parameters such as dimensions, insulation thicknesses, etc. These parameters may however be inaccurate, outdated or unavailable, due to which the model is incorrect. Using a novel calibration methodology, the unknown parameters can be improved by reducing the error of the model when comparing with measurement data. Moreover, the existing MPC has only limited support for integer control variables, long-term optimal control, or

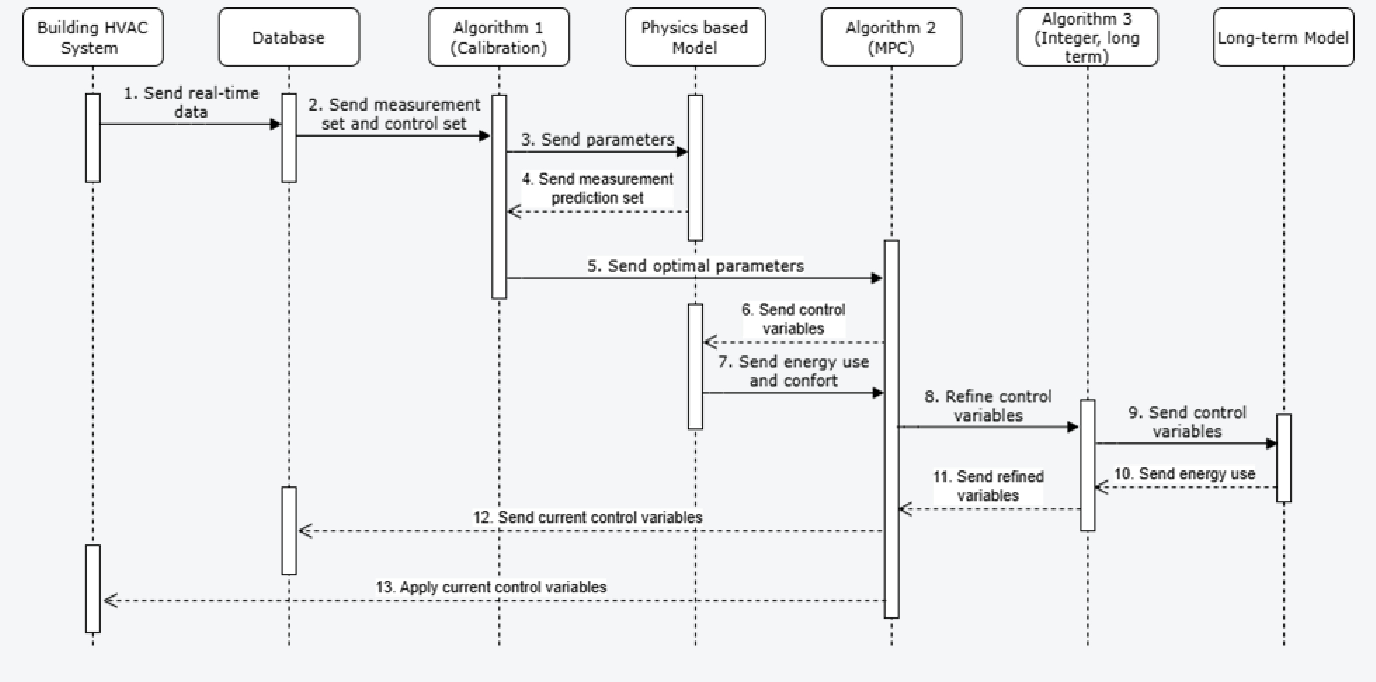
	seasonal switching decisions. To cope with this, the existing MPC-framework is generalized and extended.
Objectives of the use case	1. Develop the calibration methodology 2. Extend the MPC to improve support for integers, long-term optimal control and seasonal switching 3. Apply the methodology to the Belgian pilot 4. Verify the results: • the error reduction on the observed parameters and whether the calibrated parameter values are realistic • The improvement in control behavior and model mismatch
Limitations & Assumptions	The methodology requires sufficient sensors and qualitative measurement data. The MPC extensions are virtually tested.

Narrative of Use Case	
Short Description	The MPC model is calibrated using zone temperature measurements and other measurements related to the parameters that are intended to be calibrated. Additional algorithms are developed to extend the current MPC.
Complete Description	An MPC predicts specific variables such as zone temperature and other temperature values. Temperature measurements that correspond to these variables are often present in the real building. Ideally, the difference between those matching values is zero, meaning that the model perfectly predicts the building thermal comfort and energy use. In practice, this is, however not the case. These errors can be reduced somewhat by correcting the model initial temperatures but the effect of such corrections is limited. Correcting the model rather than correcting its initial temperatures is a more accurate way to align it with real-world building dynamics. This can be done by calibrating the model using the aforementioned measurements and variables. Firstly, the optimization objective is then reformulated such that it minimizes the model difference instead of the energy use. Secondly, the model optimizes model parameters instead of control variables. Such parameters can include the thermal conductivity of wall materials, the nominal thermal power of radiators, etc. This calibration methodology will be developed and tested. Furthermore, the MPC prediction can differ from the actual system because of simplifications in the MPC formulation. Two common simplifications in the existing white-box MPC are the neglection of long-term effects (in e.g. borefields) and considering integer control variables as continuous variables. To improve the control behavior, these effects can be considered directly in the MPC by introducing additional algorithms and/or models.

Co-funded by
the European Union

Diagrams of the UC

Sequence diagram of the use case



Technical Details of the UC

Actors			
Actor Name	**Actor Type**	**Actor Description**	**Further information specific to this Use Case**
Building Manager	Stakeholder	Responsible for overseeing the operation of the building	Uses calibrated models to determine optimal control actions while considering constraints and objectives.
Database	Software/ System	Stores data	-
Algorithm 1 (Calibration)	Software	Calibrates the physics-based model using historical and real-time data.	-
Physics-Based Model	Software/ System	Simulates the building's thermal behavior based on inputs and parameters.	-

Co-funded by the European Union

Actors			
Actor Name	**Actor Type**	**Actor Description**	**Further information specific to this Use Case**
Algorithm 2 (MPC)	Software	Computes the optimal parameter values based on the calibrated model.	-
Algorithm 3 (Integer, Long-term)	Software	Computes the optimal control actions	Extended for improved support for integers, long-term optimal control and seasonal switching
IoT Sensors	System component	Devices that measure temperature, humidity, energy use, and other relevant variables in real-time.	Provide the essential data for both model calibration and MPC operation.
IoT Gateway	System component	Device that aggregates data from sensors and meters and communicates it to the control system.	Ensures seamless data transfer and storage for model calibration and real-time control.
Heat Pumps	System Components	Required infrastructure	-

<u>Step-by-step analysis of use case</u>

Overview of scenarios

Scenario Conditions						
No	**Scenario title**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-Condition**
S01	MPC using calibrated model	Algorithm	N/A	Periodic clock	Measurement data and model predictions are available but have large differences.	The difference between predictions and measurements has decreased and new optimal results are computed.

Co-funded by the European Union

Steps per scenario

Scenario Name	**MPC using calibrated model**							
Step No.	Event	Name of Process/ Activity	Description of Process/ Activity	Service	Information Producer (Actor)	Information Receiver (Actor)	Information exchanged (IDs)	Requirements, R-ID
1	Periodic clock	Calibration preparation	Calibration data are fetched from a database and processed and saved in the correct format.	Algorithms	Database	Files	Calibration Data ID, Processed Data ID	R-01: Ensure database is accessible and data is in proper format
2	Preparation finished	Calibration start	The calibration process uses processed measurements to find optimal parameters	Algorithm	File	File	Calibrated Parameters ID, Measurement Data ID	R-02: Algorithm must be capable of processing measurement data to find optimal parameters.
3	Periodic clock	Execute MPC with optimal parameters	MPC is executed using the optimal parameters. Results are saved to file and database	Algorithm	File	File, database	Optimized Control Parameters ID, Simulation Results ID	R-03: The MPC should be capable of using the calibrated parameters and provide results.

Co-funded by the European Union

3.1.3. UC – BE 3: Iterative HVAC design to propagate the electrification of thermal energy demand

Description of the Use Case

Use case Identification		
ID	**Title**	**Domain**
BE3	Iterative HVAC design to propagate the electrification of thermal energy demand	HVAC design replication strategy

Version Management			
Version No	**Date**	**Name of authors**	**Changes**
1	14.11.24	Ann Bruggeman (Sweco), Robin Haesen (Sweco)	Initial draft Use case definition
2	15.11.24	Louis Hermans (KUL)	Additional Information Added
3	19.11.24	Lieve Helsen (KUL)	Added some clarifications and a more explicit flow
4	25.11.24	Arno Marechal (Sweco)	Additional Information Added
5	28.11.24	Ann Bruggeman (SWECO)	Control strategy (design/ fase implemented), diagram adjusted
6	01.04.25	Tsompanidou Eleni (CERTH)	Review for validation and final version

Classification Information	
Pilot Involved	BE pilot (StijnS)
Relation to Other Use Cases	Related to the Optimal Sizing Use Case
Related Innovative SEEDS solutions	– Integrated optimal control and sizing (6) – Adaptive hydronic scheme for seasonal switch (12) – Replication from BE pilot 1 to pilot 2 (36)
Assets of the UC	Hydronic seasonal switching scheme

Co-funded by the European Union

Scope and Objectives of Use Case	
Scope of the use case	This use case aims to use an iterative design methodology to propagate the electrification of thermal energy demand
Objectives of the use case	• Consider and assess feasible combinations of renewable (and residual) energy sources, tailored to the building location and program. • Use standardized design blocks to couple the different renewable energy (sub)systems in order to obtain a hybrid supply for the heat (and cold) demand and an optimized energy efficiency, at the same time ensuring a logical and cost-effective exploitation scheme. • Monitor the effectiveness of the built HVAC installation through continuous commissioning, feeding this information back to optimize new, future HVAC designs. ◦ Feedback loop from previously validated design decisions and the continuous commissioning into the iterative design process to create a database for similar projects.
Limitations & Assumptions	• Combining standardized design blocks often results in too many components (filters, valves, …), a critical review and further optimization of the scheme as a whole is necessary. • Assessing the sizing of the technologies based on intermittent renewable sources always entails a risk. Looking for the complementarity of technologies in hybrid energy systems also entails a risk, as redundant systems should be avoided. • Sizing of the (sub)systems highly depends on the control strategy to be implemented. • Feedback loop is necessary to enable new similar designs to benefit from previous research and to ensure dissemination of all lessons learned.

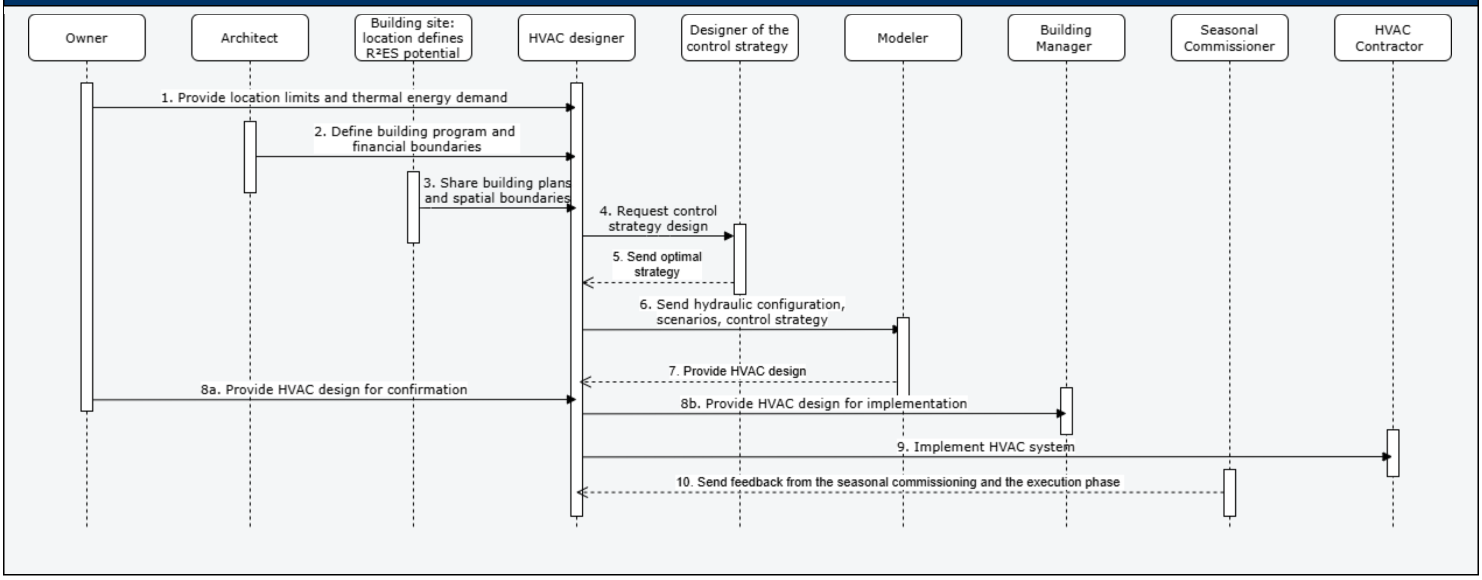
Narrative of Use Case	
Short Description	The iterative design of hybrid HVAC solutions eventually will facilitate the optimal design of hybrid systems, with an optimized configuration of different subsystems, based on the renewable energy source potential, to ensure high annual performance. The necessary components that link the different subsystems ensure the functioning of different scenarios, depending on the aforementioned system efficiency that may vary over seasons. Once their effectiveness is shown in several projects (including continuous commissioning), the propagation of the design methodology can be quantified and will increase the electrification of thermal energy demand.

Co-funded by
the European Union

Complete Description	Depending on the location, renewable (and residual) energy sources are identified, together with an estimation of their potential. A first spatial planning that indicates roughly the needed space for the technical equipment is drawn (available and usable roof area, available and accessible terrain for borefields, volume of buffer tanks, …). Once the renewable (and residual) energy sources are identified, the subsystems can be implemented in the hydronic scheme, using standardized design blocks. The hydronic scheme is assessed, using different scenarios that allow the different subsystems to work separately or in combination with other subsystems, depending on the seasonal performance of each subsystem and the thermal energy need of the building. The optimized combination of different components as well as certain component sizes is an exercise to minimize the sum of OPEX and CAPEX, including a selected control strategy. From a first feedback loop, the design choices and their corresponding reasoning is added to a database which can be consulted in a following project. Once the HVAC installation is built, the performance is checked through continuous commissioning, feeding this information back in a second feedback loop to optimize new, future HVAC designs.

__Diagrams of the UC__

Sequence diagram of the use case



Technical Details of the UC

Actors			
Actor Name	**Actor Type**	**Actor Description**	**Further information specific to this Use Case**
Building site	Building site	-Location limits the potential of R2ES -Building program and occupational needs define thermal energy demand	Input for the process
Building owner	Stakeholder, Formal decision taker	-Defines the building program - Approves the design and execution file, puts the execution file in the market	- Input for the process - Tendering of the chosen solution: launch, assess (in close collaboration with the engineering firm) and award the contractor who will implement the design
Architect	Stakeholder	Provides the building plans	Input for the process
HVAC designer	Stakeholder	- Designs the thermal system -Verifies the different scenarios (including control strategy) and system efficiency - Finalizes hydronic switch scheme - Feeds back the design choices to a database	- Input for the process, that outputs the HVAC design - Assist awarding of the tender, implementation of the real-life solution - reference data (input/ set points) for the continuous commissioning
Modeler	System	Models the buildings and thermal system and simulates the system under different scenarios, using the selected control strategy.	Input for the process

Co-funded by
the European Union

Actors			
Actor Name	**Actor Type**	**Actor Description**	**Further information specific to this Use Case**
Designer of the control strategy	Designer of the control strategy	Designs the made-to-measure control strategy	Defines the desired KPI's for the thermal system (control setpoints of the HVAC system)
HVAC contractor	Contractor	Implements the HVAC equipment on site according to the execution documents	Implements the HVAC equipment in real-life conditions to enable the real time switching of the HVAC hybrid scheme
Building Facility manager	Stakeholder	Daily management of the energy system	A good understanding of the overall building energy system is necessary to safeguard longevity of the installation
Seasonal Commissioner	Seasonal Commissioner	- Evaluates the real life performance of the thermal system design - Feeds back the lessons learned of the continuous commissioning to a database	Both input for future designs as output to evaluate the assessed HVAC installations

<u>Step-by-step analysis of use case</u>

Overview of scenarios

Scenario Conditions						
No	**Scenario title**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-Condition**
S01	Assess feasible renewable (and residual) energy sources	The HVAC designer assesses different options linked to the building site	HVAC designer	Renovation or decarbonisation of the thermal energy supply is necessary	Investment budgets/ financial boundaries are agreed upon	Feasibility study of R2ES

Scenario Conditions						
No	**Scenario title**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-Condition**
S02	Define the hybrid solution: combination and complementarity check of subsystems and different scenarios	The HVAC designer decides on a hydraulic configuration and sends it to the modeler	HVAC designer	The HVAC designer has finalized the hydraulic schemes	Hydraulic configuration is agreed upon	sent
S03a	Iterative design: optimal control strategy	Designer of the control strategy develops the optimal control strategy based on the building and HVAC design	Control designer	The HVAC designer has finalized the hydraulic schemes, building plans are finished	Building plans, hydraulic configuration are ready and agreed upon	Control strategy, ID of monitored components and reference set points defined
S03b	Iterative design: optimal sizing of the components	The modeler develops the dynamic system model and simulates the system using the selected control strategy.	Modeler	Modeler receives hydraulic configuration, scenarios, control strategy and building plans	Building plans, hydraulic configuration and control strategy are ready	dynamic system model is ready and simulated.
FBA	Feedback loop 1	Feedback from the design process to the database	Modeler	The HVAC design is finished	The HVAC design is finished	Database is updated with feedback from design
S04a	Tendering process to implement HVAC	introduce HVAC design for implementation in the market and award tender	Building owner	Final design is incorporated in execution file	HVAC designer has checked all execution files	Contractor is appointed to implement HVAC equipment

Co-funded by the European Union

Scenario Conditions						
No	Scenario title	Scenario description	Primary actor	Triggering event	Pre-condition	Post-Condition
S04b	HVAC-scheme execution	Install and implement HVAC solution on site	Building owner	Tender is awarded	Contractor is assigned and execution is ordered	Installation of HVAC equipment on site
S05	Continuous Commissioning	Seasonal commissioning of the installation	Seasonal Commissioner	The installation is installed and running for a certain period	The installation is installed and running for a certain period	The operation of the installation has been reviewed
FBB	Feedback loop 2	Feedback from the seasonal commissioning and the execution phase to the database.	Seasonal Commissioner	The results from the seasonal commissioning are available	A phase of seasonal commissioning is finished	Database is updated with feedback from seasonal commissioning

Steps per scenario

Scenario Name: Assess feasible renewable (and residual) energy sources								
Step No.	Event	Name of Process/ Activity	Description of Process/ Activity	Service	Information Producer (Actor)	Information Receiver (Actor)	Information exchanged (IDs)	Requirements, R-ID
1	program analysis	program analysis	Definition of site-bound key figures: based on the building program and building address, define the need for power (electrical, heating, cooling, ventilation)	send	EPB, integrated performance systems designer	HVAC designer	Estimation of power needed, based on the building program	Estimation tools used during sketch design (estimate power needed for ventilation heating, cooling, electrical volumes (incl plugloads); asses R²ES potential

								based on site address
2	Building envelop analysis	Building envelop analysis	Definition of site-bound key figures: based on the building envelope (existing or new construction). In case of an existing building: analysis of the available As-Built information.	send	Building physicist	EPB HVAC designer	Definition of the preferred characteristics of the building envelope and potential energy systems. Estimation of the (current or desired) airtightness.	Characteristics of building materials (U-values, LCA), energy systems requirements (concepts)
3	Site visit	Visual verification of As-Built information and spatial feasibility of chosen solutions	Confirmation of the building envelop characteristics on site to confirm the assumptions based on the As-Built info; confirm the spatial feasibility of chosen solutions	Send	Building physicist, integrated performance systems designer	HVAC designer	Confirm	Confirmation of the assumed characteristics, of spatial possibilities on site, of the building materials (U-values, LCA), of the potential energy systems requirements (concepts)
4	Heath loss calculation / simulation	Heath loss calculation/ simulation	Definition of site-bound key figures: power demand based on the specific site and	Send	EPB, integrated performance systems designer,	HVAC designer	Estimation of power needed, based on the building volume and	Estimation tools used during sketch design (heat loss calculation,

			program (existing or new construction).		HVAC designer		characteristic, orientation on site, thermal validation of the building envelope, estimation of the (current or desired) airtightness included	building simulation, other)

Scenario Name: Define the hybrid solution: combination and complementarity check of subsystems and different scenarios								
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
1	Define the hybrid solution		HVAC designer is provided with guidelines to design suitable hybrid solutions	send	HVAC designer	modeler	Scope and basic potential configurations (scenario's) of hybrid solutions for a specific site	HVAC design, simulation

Scenario Name: Iterative design: optimal control strategy								
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
1	Define the control strategy	Definition of the control strategy	HVAC designer is provided with guidelines on how to control the hybrid energy systems	send	Control strategy designer	HVAC designer	Scope and basic configuration of the control strategy for potential scenario's for a specific site	control design for (centralized and decentralized) energy systems
2	Define the required instrumentation to implement	Definition of I/O	HVAC designer prescribes the optimal hardware &	defined	HVAC designer	HVAC designer, control strategy designer	Definition of the hardware and communication characteristics	Final execution design, Tender docs

Co-funded by the European Union

	the control strategy		sensors needed to implement the control strategy				to facilitate the control of the system for potential scenario's for a specific site	

Scenario Name: Iterative design: optimal sizing of the components								
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
1	Define the optimal sizing of components	optimal sizing of components	Modeler is provided with precise characteristics of the hybrid energy systems and the control strategy and defines through simulation the optimal sizing of components	send	Modeler	HVAC designer	Optimal sizing of components for potential scenario's for a specific site	Simulations, analysis of the different scenarios through simulations

Scenario Name:	**Feedback loop 1**							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
1	Optimal hybrid energy systems and control strategy are defined and ready for tendering	Feed key prestation figures related to the hybrid systems to a dedicated project reference database	Engineering company collects and saves key figures into a dedicated project reference database	Database had been updated	HVAC designer	HVAC designer, Seasonal Commissioner	Optimal hybrid energy system and control strategy for a specific site	Project reference database: assumptions made on the building envelop and the technical installations prescribed

Scenario Name: Tendering and installation of HVAC equipment								
Step No.	Event	Name of Process/ Activity	Description of Process/ Activity	Service	Information Producer (Actor)	Information Receiver (Actor)	Information exchanged (IDs)	Requirements, R-ID
1	Optimal hybrid energy systems and control strategies are defined and ready for tendering	Tendering process to determine a suitable contractor	Engineering company checks technical characteristics of the offer, building owner checks formal preconditions to assign the best execution partner	Tendering process	Building owner with the support of an engineering company	contractors	Supply necessary information to enable the introduction of viable offers regarding the execution of the HVAC scheme	Financial and technical approval of the tender documents by the site owner, as well as the engineering company
2	Award tender	Award tender	Financial and technical approval of the offers introduced, both by the site owner as well as the engineering company, to assign the most suitable contractor	Tendering award process	Building owner with the support of an engineering company	contractor	Tender awarded yes/ no	Demonstrate suitability to execute the HVAC design
3	Execute tender documents	Execution of HVAC equipment	Follow-up of the implementation of the design on site	Execution coordination	Contractor, Supervised by an engineering company	Building owner with the support of an engineering company	As built info	Financial and technical approval of the execution by the site owner, as well as the engineering company

Scenario Name: Continuous Commissioning								
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
1	Optimal hybrid energy systems and control strategy are implemented and operational	Measure and monitor the hybrid energy system and control strategy onsite	Engineering company and/ or building owner collects and monitors key performance indexes linked to the hybrid energy systems	Commissioning plan is delivered and being executed	Seasonal Commissioner	Seasonal Commissioner, building owner	Commissioning data for a specific site	Monitoring reports, ideally fed into the project reference database

Scenario Name: Feedback loop 2								
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
1	Installed hybrid energy systems and control strategy are being monitored on site, measurements are available	Feed key monitoring figures to a dedicated project reference database, based on real-life measurements	Engineering company collects and saves key monitoring figures into a dedicated project reference database	The database had been updated	Seasonal Commissioner	HVAC designer, building owner, maintenance company	Real-life data on hybrid energy systems and control strategy for a specific site	Project reference database

3.1.4. UC – BE 4: Improving thermal system designs by using integrated optimal design methodologies

Description of the Use Case

Use case Identification		
ID	**Title**	**Domain**
BE4	Improving thermal system designs by using integrated optimal design methodologies	HVAC design optimization

Version Management			
Version No	**Date**	**Name of authors**	**Changes**
01	29.08.24	Louis Hermans (KUL), Ann Bruggeman (Sweco), Filip Jorissen (BWS)	First draft
02	01.04.25	Tsompanidou Eleni (CERTH)	Review for validation
02	06.04.25	Lieve Helsen (KUL)	Asset added

Classification Information	
Pilot Involved	BE pilot (StijnS)
Relation to Other Use Cases	Related to the MPC UC as MPC is used in this use case. Related to the iterative HVAC design use case.
Related Innovative SEEDS solutions	– Integrated optimal control and sizing (6) – Extension of white-box MPC to multi energy vector district systems (22)
Assets of the UC	Algorithm to optimally size thermal system components thereby using optimal control, as such reducing both CAPEX and OPEX

Co-funded by the European Union

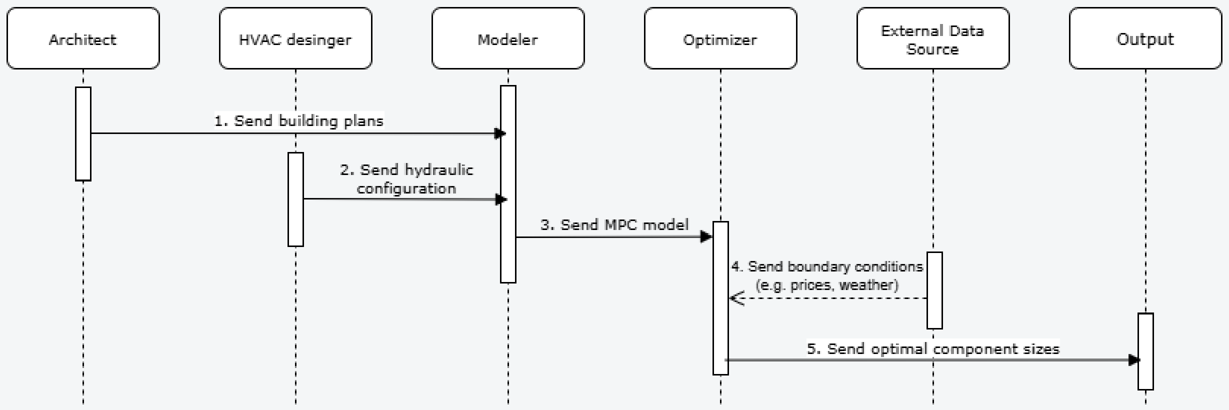
Scope and Objectives of Use Case	
Scope of the use case	This use case aims to use an integrated optimal design and control methodology to optimally size thermal systems.
Objectives of the use case	• Consider the flexibility exploitation potential of optimal control during the design of the thermal system • Minimize the CAPEX and OPEX of the system simultaneously Guarantee thermal comfort of the eventual users of the system
Limitations & Assumptions	• Detailed building models are required during the design phase • Assumptions on future boundary conditions have to be made and are uncertain. • Assumptions on user behavior have to be made and are highly uncertain. Due to these uncertainties the sizes obtained are the lower limits and need to be subjected to stress tests.

Narrative of Use Case	
Short Description	In this use case, the sizes of components in the thermal system (HPs, borefield, tanks, …) are optimized by taking into account the eventual operational optimal control policies. The flexibility exploitation of optimal control is considered during the design phase and can prevent unnecessary oversizing of expensive components. This makes that CAPEX and OPEX are minimized together.
Complete Description	Building plans together with a corresponding hydraulic scheme of the thermal system are made. Once these are finished, a detailed controller model of the entire system is developed. This MPC model is then used in the inner loop of a nested optimization to determine the optimal control schemes by MPC for a certain combination of component sizes. This allows to find the combination of component sizes that minimizes the sum of OPEX and CAPEX. Oversizing is avoided by exploiting the flexibility present in the system. This is automatically done by the MPC in the inner loop of the nested optimization. Assumptions on future boundary conditions (weather, prices, …) are made. For prices different scenarios are considered and for weather conditions both TMY and EMY files are used, the latter to perform some stress testing.

Co-funded by
the European Union

Diagrams of the UC

Sequence diagram of the use case



Technical Details of the UC

Actors			
Actor Name	**Actor Type**	**Actor Description**	**Further information specific to this Use Case**
HVAC designer	Stakeholder	Designs the thermal system	Input for the process, that outputs proper (cost-effective) sizing of thermal systems
Architect	Stakeholder	Provides the building plans	Input for the process
Modeler	System	Models the buildings and thermal system	Input for the process
Optimizer	Algorithm	The algorithm optimizes 2 nested loops	Generation of output: optimal sizes

Step-by-step analysis of use case

Overview of scenarios

Scenario Conditions						
No	**Scenario title**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-Condition**
S01	Building plans are sent	The architect makes the building plans and sends them to the modeler.	Architect	Building plans are ready	Building design is agreed upon	sent
S02	Hydraulic configuration is sent	The HVAC designer decides on a hydraulic configuration and sends it to the modeler	HVAC designer	The HVAC designer has finalized the hydraulic schemes	Hydraulic configuration is agreed upon	sent
S03	Development of MPC model	The modeler develops the MPC model	Modeler	Modeler receives hydraulic configuration and building plans	Building plans and hydraulic configuration are ready	MPC model is ready
S04	Integrated control and size optimization	The optimization algorithm runs.	Optimizer	The MPC model is ready and the boundary conditions are chosen	MPC model ready and boundary conditions chosen	Components are optimally sized

Steps per scenario

Scenario Name		**Building plans are sent**						
Step No.	Event	Name of Process/ Activity	Description of Process/ Activity	Service	Information Producer (Actor)	Information Receiver (Actor)	Information exchanged (IDs)	Requirements, R-ID
1	Building plans are ready	Sending of building plans	The architect sends the buildings plans to the modeler	send	Architect	Modeler	Building plans	

Scenario Name		**Hydraulic configuration is sent**						
Step No.	Event	Name of Process/ Activity	Description of Process/ Activity	Service	Information Producer (Actor)	Information Receiver (Actor)	Information exchanged (IDs)	Requirements, R-ID
1	Building plans are ready	Sending of building plans	The architect sends the buildings plans to the modeler	send	Architect	Modeler	Building plans	

Scenario Name		**Development of MPC model**						
Step No.	Event	Name of Process/ Activity	Description of Process/ Activity	Service	Information Producer (Actor)	Information Receiver (Actor)	Information exchanged (IDs)	Requirements, R-ID
1	Modeler receives hydraulic configuration and building plans	Development of MPC model	The modeler develops the white-box MPC model using existing tools.	development	Modeler	Modeler	MPC model	
2	MPC model is ready	Sending MPC model to optimization algorithm	The modeler sends the finished MPC model to the optimizer to be used for the integerated control and size optimization	send	Modeler	Optimizer	MPC model	

Co-funded by the European Union

Scenario Name		**Integrated control and size optimization**						
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
1	Optimizer receives the MPC model	Receiving of MPC model	The optimizer receives the MPC model from the modeler	send	Modeler	Optimizer	MPC model	
2	Optimizer receives the boundary conditions	Receiving boundary conditions	The boundary conditions are given to the optimizer	send	Extern	Optimizer	Boundary condtions	
3	Optimizer Receives boundary conditions and MPC model	Performing optimization	The optimizer performs the integrated control and sizing optimization	optimizing	Optimizer	Output	Optimal component sizes	

3.2. USE CASES OF DANISH PILOT (DK)

3.2.1. UC – DK 1: Capturing of telemetry data

Description of the Use Case

Use case Identification		
ID	**Title**	**Domain**
DK1	Capturing of telemetry data	Data management

Version Management			
Version No	**Date**	**Name of authors**	**Changes**
01	21.11.24	Marie-Louise Krogh (CDK)	Proposal of use case

Classification Information	
Pilot Involved	Danish Pilot, Tech House building, led by Center Denmark, supported by DTU - Compute, Dandy Business Park, Enfor and AI-Nergy
Relation to Other Use Cases	– UC – DK 2: Model predictive control using Grey-Box model for the Danish Pilot – UC – DK 3: Flexibility function integrated flexibility service Related to Use cases for Danish pilot building "Tech House"
Related Innovative SEEDS solutions	– Digital platform connecting BMS and real-time electricity prices – Data quality assurance mechanism – Upgrade of existing platforms for near real time data acquisition and control
Assets of the UC	Tech House is an office building under construction and will be ready for use by medio 2025. Automations systems, IoT and solar panels are planned and the planning of an establishment of battery power storage is ongoing right now. The building is much like an existing building and therefore many of the systems planned for use are already known to the pilot site owner.

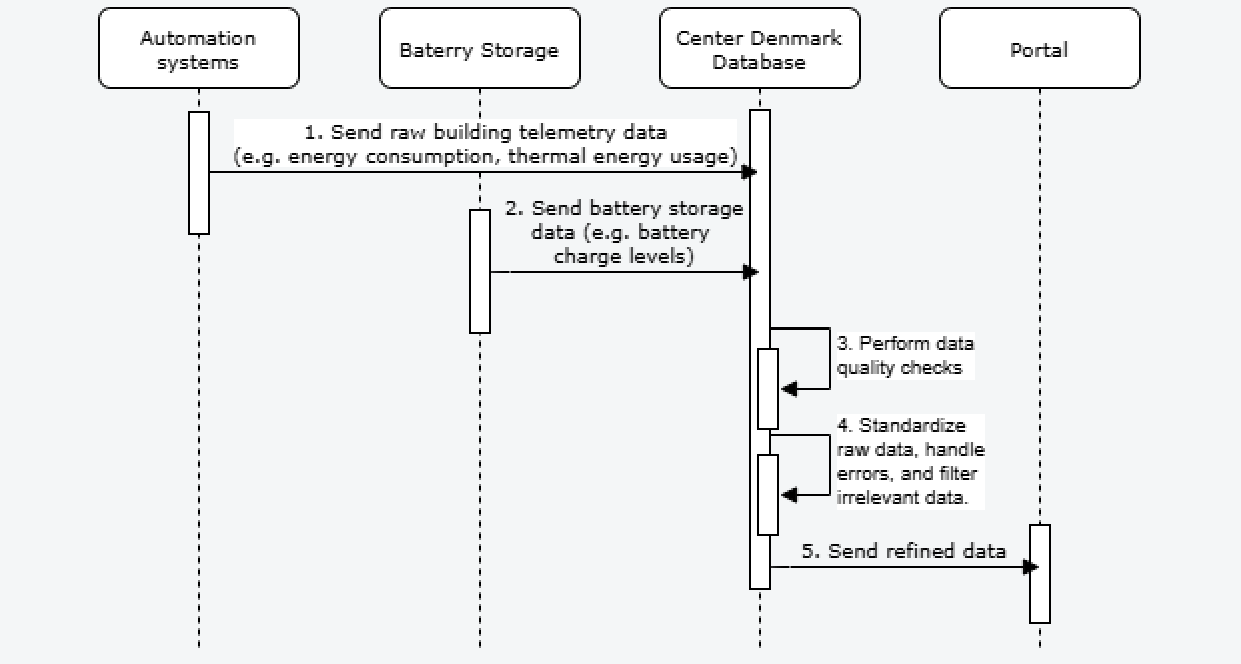
Scope and Objectives of Use Case	
Scope of the use case	The scope of this use case focuses on facilitating a digital platform for data collection from the Danish pilot building “Tech House”, where data flows from the buildings different automation systems to the platform. Enhancing data sets of relevance to partners. Through a process of collecting knowledge of possible automations systems, required supplementary data from e.g. weather, building BBR system, new IoT requirements from the building and battery power storage. Identifying the needs for cleaning and optimizing the data sets to a degree possible and relevant for the partners using the data. Making the data accessible to named partners and facilitate implementation of a constant flow of data as part of an optimal system operation
Objectives of the use case	1. Identify relevant datasets for the data platform relevant to partners for digital twin modelling 2. Establish data flow using the best suitable technology 3. Optimization of data 4. Create and maintain user rights and access of data through portal 5. Secure data platform and data availability throughout the project
Limitations & Assumptions	The Danish Pilot is still in the construction phase, we rely on the existing knowledge on automations systems used in similar buildings belonging to same building owner.

Co-funded by
the European Union

Narrative of Use Case	
Short Description	The Digital platform collects data on relevant automation systems for pilot site building "Tech House" and facilitates optimal and secure data delivery to project partners.
Complete Description	Center Denmark facilitates the collection, integration, and delivery of data from the automation systems of the Tech House pilot site. Leveraging data from multiple sources, including local data systems (consumption gateways, solar inverters, battery management systems, etc.), and weather data, the data pipeline is structured across four layers within a data warehouse: Landing, Bronze, Silver, and Gold. In the Landing layer, raw data, such as energy consumption, thermal energy usage, and actuator positions, is ingested directly from APIs and sensors. This raw information includes both exteroceptive measurements (consumption metrics) and proprioceptive measurements (e.g., battery charge levels, EV charger statuses). The Bronze layer processes this raw data, standardizing formats, handling errors, and filtering irrelevant data to create a structured and reliable dataset. The Silver layer performs transformations, enriching datasets with contextual metadata and applying business logic. Finally, in the Gold layer, data is refined optimized for specific applications, such as indoor air quality monitoring, energy optimization, and predictive maintenance. These datasets are delivered securely via the Center Denmark portal, enabling researchers to analyze building management systems and optimize energy use. Through Center Denmark's portal the data can be accessed via API or simply downloaded in batches via the web browser. The data is visible and accessible to our partners when they have registered to the portal, and access has been granted.

Diagrams of the UC

Sequence diagram of the use case



Technical Details of the UC

Actors			
Actor Name	**Actor Type**	**Actor Description**	**Further information specific to this Use Case**
Automation systems	Software	Data collection from the building systems	N/A
Battery Storage	Software	Data from the storage	N/A
Center Denmark Database	System	Stores data.	N/A
Dandy Business Park	Pilot site owner	Stakeholder management and integration to systems delivering data	N/A

Step-by-step analysis of use case

Overview of scenarios

Scenario Conditions						
No	**Scenario title**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-Condition**
S01	Identification of data sources	Collaboration between site owner and development partners identifying relevant data sources	CDK	Physical meeting	Which data sources are relevant and needed	Identified relevant data sources and possible integration technologies
S02	Integration to data sources	Set up integration to the relevant sources from site building	CDK	Meetings with relevant data suppliers	Legal agreements in place	Data flow is established and tested
S03	Data quality	Data check to make sure quality and quantity fits needs	CDK, DTU, Enfor, AI-nergy	Data accessible on CDK landing platform	Scenario 02	The data is of right quality and quantity and relevant corrections are made
S04	Data accessible for relevant partners	The data is processed in the required manor and made available through portal where the relevant users have access	CDK	Data has been transformed, enriched and refined to the need of the partners	Data flow from pilot site and user/partner access defined	The partners have access to the data through the portal throughout the project

Steps per scenario

Scenario Name	S01 – Identification of data sources							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
S01	Meeting	Identify automation data points	Site owner and CDK meet to identify available data points from CTS (e.g. indoor climate, ventilation, energy use)		Dandy Business Park	CDK	List of available data points	-
S02	Setup	Data export from CTS system	Configure export of selected CTS data to external sFTP server		Dandy Business Park	CDK	Selected relevant tags	-

Scenario Name	S02 – Integration to data sources							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
S01	Setup	Data export from CTS system	Configure export of selected CTS data to external sFTP server		Dandy Business Park	CDK	Export configuration	Secure transfer
S02	Ingestion	Setup NiFi flow for ingestion	Establish NiFi flow to extract data from sFTP and load into the Landing zone of the datalakehouse		CDK	CDK	NiFi flow config	Data mapping
S03	Test	Integration test	Verify successful ingestion and completeness of data		CDK	CDK	Test log results	Validation protocol

Co-funded by the European Union

Scenario Name	S03 – Data quality							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
S01	Cleaning	Clean raw data in Bronze layer	Apply standardization, error handling, and removal of irrelevant data		CDK	CDK	Cleaned dataset log	Data quality threshold
S02	Enrichment	Enrich in Silver layer	Add metadata and apply context-aware transformation using business logic		CDK	CDK	Enriched data schema	Metadata consistency
S03	Validation	Partner verification	Partners review quality of available data through test access		CDK	DTU, Enfor, AI-nergy	Validation report	Partner feedback loop

Scenario Name	S04 – Data accessible for relevant partners							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
S01	Authorization	Setup user access management	Define access rights based on partner roles	Portal	CDK	Partner Organizations	Access matrix	Role-based access
S02	Deployment	Provide data via Gold layer	Make refined data accessible through API and portal interface	Portal	CDK	DTU, Enfor, AI-nergy	Data access endpoint	Availability SLA
S03	Maintenance	Monitor access and performance	Track usage and performance metrics to ensure continuity		CDK	CDK	Usage stats	Monitoring plan

Co-funded by the European Union

3.2.2. UC – DK 2: Model predictive control using Grey-Box model for the Danish Pilot

Description of the Use Case

Use case Identification		
ID	**Title**	**Domain**
DK2	Model predictive control using Grey-Box model for the Danish Pilot	Energy efficiency and flexibility activation

Version Management			
Version No	**Date**	**Name of authors**	**Changes**
01	30.10.2024	Shahab Tohidi (DTU - Compute)	Definition of the Use Case
02	02.04.2025	Eleni Tsompanidou (CERTH)	Review
03	05.04.2025	Shahab Tohidi (DTU - Compute)	Additional info added

Classification Information	
Pilot Involved	Danish Pilot
Relation to Other Use Cases	– UC – DK 1: Capturing of telemetry data
Related Innovative SEEDS solutions	– Novel heating/cooling system using low-temperature district heating & high temperature cooling (3) – Platforms for near real time data acquisition and control
Assets of the UC	Tech House

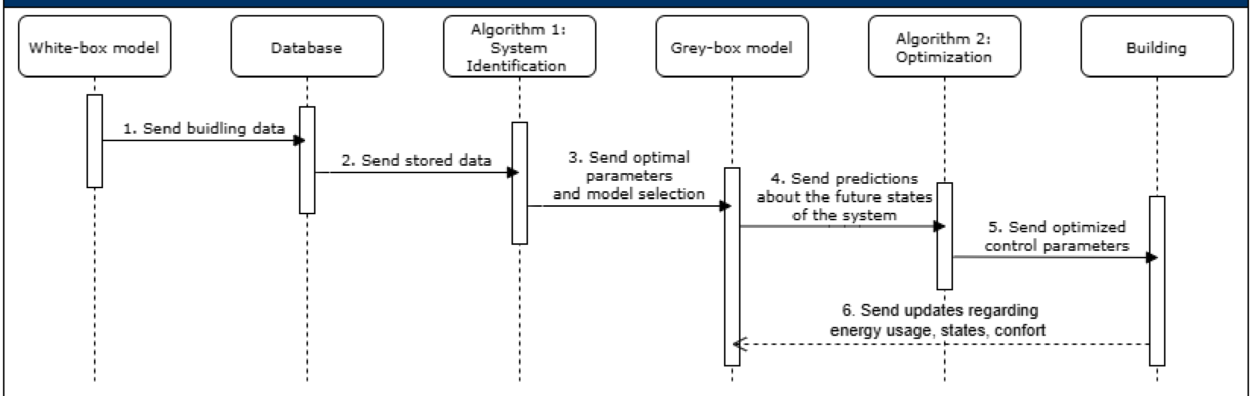
Scope and Objectives of Use Case	
Scope of the use case	The scope of this use case focuses on enhancing energy efficiency and flexibility in building energy systems through the application of model predictive control (MPC) supported by grey-box modeling. This approach requires identification of a low dimensional representations of building energy systems that balance accuracy with computational efficiency using statistical analysis. Utilizing the grey-box model enables the controller to predict changes in energy demand, react to external factors like weather conditions and occupancy patterns, and dynamically adjust heating, ventilation, air

	conditioning (HVAC), and other building systems. Furthermore, the approach integrates flexibility activation, allowing the building to respond to grid demands and price signals, potentially lowering operational costs and contributing to grid stability.
Objectives of the use case	1. Data collection from white-box representation of the Danish Pilot 2. Develop model selection and parameter identification for grey-box modelling 3. Model predictive controller design using grey-box model 4. Apply the control methodology to the Danish pilot (white-box) 5. Verify the results
Limitations & Assumptions	Since the Danish Pilot is still in the construction phase, we have to rely on white-box model data instead of real building data. We are working on in parallel to include real-time data from a similar existing building.

Narrative of Use Case	
Short Description	Model predictive control design for energy efficiency and flexibility activation
Complete Description	Using data generated from a white-box model and statistical analysis we find a low-dimensional model that represents the data properly. This grey-box model is then utilized to predict the states of the system for the model predictive controller. The controller is designed such that it takes care of the technical constraints and improves energy efficiency and flexibility activation.

Diagrams of the UC

Sequence diagram of the use case



Technical Details of the UC

Actors			
Actor Name	**Actor Type**	**Actor Description**	**Further information specific to this Use Case**
Database	System	Stores data.	
Algorithm 1	Software	System identification, including model selection and parameter identification	-
Algorithm 2	Software	Computes the optimal control command.	-
White-box model	Software	Detailed simulation model of the building	-
Grey-box model	Software	Low-dimensional model of the building	It receives measurements from the building and forecasts from forecasting services—
Building	System	-	-

Step-by-step analysis of use case

Overview of scenarios

Scenario Conditions						
No	**Scenario title**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-Condition**
S01	White-box model	White-box model	Using detailed information about the building and HVAC system, a white-box model is developed	-	Detailed information about the building and HVAC system should be accessible	The generated data should be collected in a data base in a proper format
S02	System identification	Algorithm 1	Using statistical analysis and machine learning methods, a low dimensional model is selected, and its parameters are identified	-	Rich data set is needed so that the parameters can be identified accurately	The identified model (grey-box) can then be used in MPC.

S03	Grey-box model	Grey-box model	Providing prediction about the future states of the system	-	Measurement of the current states or their estimation needs to be provided	-
S04	Optimization	Algorithm 2	Optimal control command is found by solving the optimization algorithm while considering technical constraints	-	Cost function and the constraints should be determined based on the objectives	Tuning of the controller is required to improve the performance
S05	Building (White-box model)	System	The controllable devices in the building are controlled by the control command		-	The system is evaluated in terms of energy use, comfort, and the state values

Steps per scenario

Scenario Name	S01 – White-box model							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
St01	Request	Request for data	White-box model generates data in an appropriate format	Generate datasets with the requested resolution and period	White-box model	Database	Information about energy consumption and thermal dynamics	-

Scenario Name	S02 – System identification							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
St02	Request	Request for optimal parameter estimation	System identification generates optimal model structure and parameters	Limit on the complexity of the model can be requested	System identification	Grey-box model	Information about model structure and model parameters	-

Scenario Name	S03 – Grey-box model							
Step No.	Event	Name of Process/ Activity	Description of Process/ Activity	Service	Information Producer (Actor)	Information Receiver (Actor)	Information exchanged (IDs)	Requirements, R-ID
St01	Request	Measurement and estimation	Measurements from building and estimation values are collected	Data should be provided in an specific sample time	Building	Grey-box model	Building energy consumption and thermal data	-
St02	Request	Prediction	Grey-box model uses the current measurements as well as the forecasts to predict future states of the building	-	Grey-box model	Optimization	Depending on the optimization cost function, Grey-box model provides the required data	-

Scenario Name	S04 – Optimization							
Step No.	Event	Name of Process/ Activity	Description of Process/ Activity	Service	Information Producer (Actor)	Information Receiver (Actor)	Information exchanged (IDs)	Requirements, R-ID
St01	Request	Receive prediction	Predictions provided by the Grey-box model are received	-	Grey-box model	Optimization	Time series of prediction of building energy consumption and thermal states	-
St02	Request	Optimal control command generation	Optimization problem is solved considering technical and comfort constraints	-	Optimization	Building	Control command depends on the system to be controlled	-

Scenario Name	S05 – Building							
Step No.	Event	Name of Process/ Activity	Description of Process/ Activity	Service	Information Producer (Actor)	Information Receiver (Actor)	Information exchanged (IDs)	Requirements, R-ID
St01	Request	Measurement data	Provides measurements of building thermal states and consumption	Data should be provided in a specific sample time	Building	Grey-box model	Building energy consumption and thermal data	

3.2.3. UC – DK 3: Flexibility function integrated flexibility services

Description of the Use Case

Use case Identification		
ID	**Title**	**Domain**
DK3	Flexibility function integrated flexibility services	Energy Efficiency, DER

Version Management			
Version No	**Date**	**Name of authors**	**Changes**
01	14.11.24	Shahab Tohidi (DTU - Compute)	Definition of the Use case
02	01.04.25	Eleni Tsompanidou (CERTH)	Review
03	05.04.25	Shahab Tohidi	Final

Classification Information	
Pilot Involved	Danish pilot
Relation to Other Use Cases	– UC – DK 2: Model predictive control using Grey-Box model for the Danish Pilot
Related Innovative SEEDS solutions	– Flexibility characterization using flexibility function, – Optimal penalty signal generation for low-level controllers – Ancillary services via the employment of flexibility function in optimization – Optimal PV and battery operation for DSO grid support
Assets of the UC	Chiller, district heating substation setpoint, PV

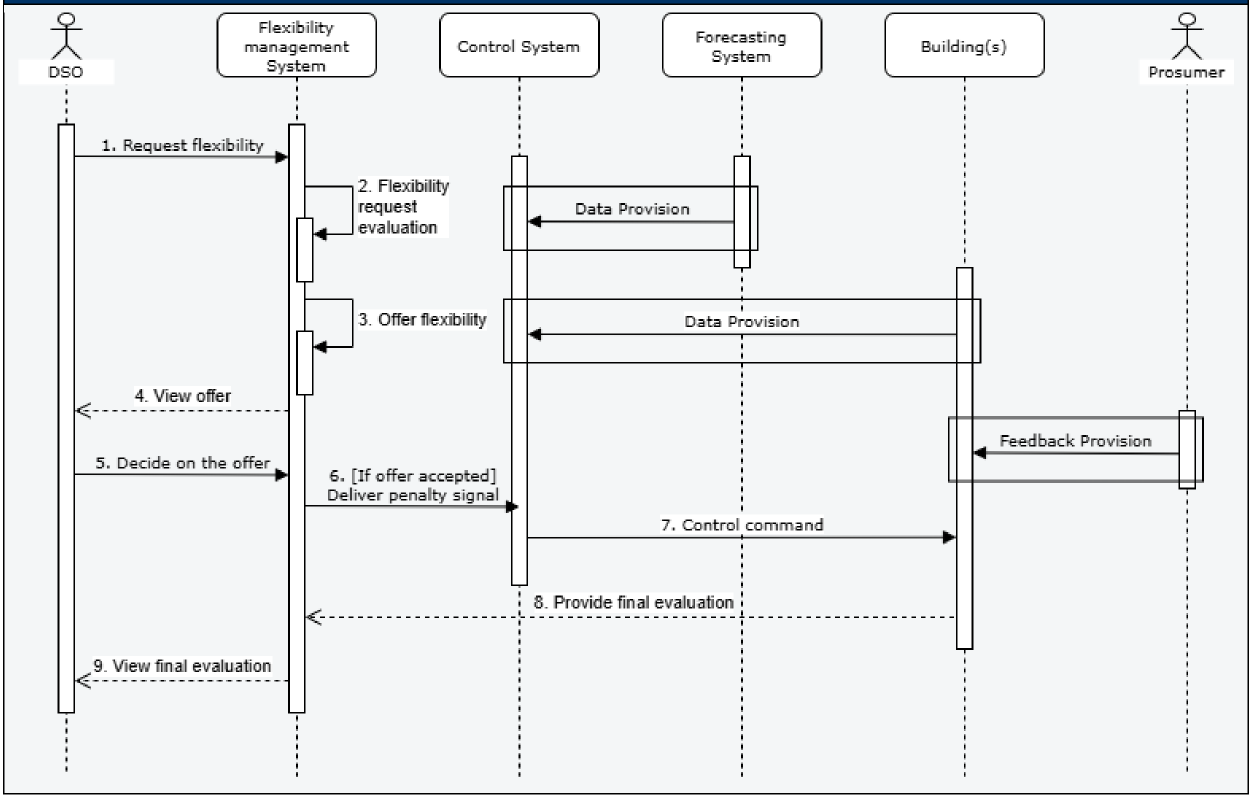
Co-funded by
the European Union

Scope and Objectives of Use Case	
Scope of the use case	The scope of this use case includes analysis, optimization and real-time management of flexibility services, as well as energy efficiency.
Objectives of the use case	1. Deploy energy flexibility of buildings 2. Enhance the stability of the electricity grid in connection with DSOs by providing ancillary services. 3. Develop methods for calculating DSO flexibility needs 4. Develop the minimum components for enabling flexibility services using the flexibility function. 5. Provide energy efficiency. 6. Optimal planning of PV and battery
Limitations & Assumptions	Regulatory conditions, Technological boundaries (lack of heat pump and storage tank, and batteries)

Narrative of Use Case	
Short Description	In response to a flexibility request by a DSO, an analysis of the energy flexibility potential of the available assets is made by a flexibility management system via the flexibility function. An optimization problem is then solved, which results in an optimal penalty signal generation. The penalty signal is then transferred to an incentive-responsive control to change the setpoints of the HVAC system.
Complete Description	Once a request is received from DSO, the flexibility management system uses digital twins to predict the demand over the specified period. One of the key tools in this process is the flexibility function, which is used to predict price-responsive demand. Furthermore, the flexibility management system generates an optimal incentive/price signal for the controller. The control system then utilizes this signal, along with real-time measurements and forecasts, to generate optimal commands to the building. Additionally, prosumers contribute to demand shaping and demand-side management by adjusting their consumption patterns in response to these price signals.

Diagrams of the UC

Sequence diagram of the use case



Technical Details of the UC

Actors			
Actor Name	**Actor Type**	**Actor Description**	**Further information specific to this Use Case**
Prosumer	Stakeholder	The end user that consumes and produces electricity	Consider as uncontrollable actor whose decisions affects the demand and flexibility potential
DSO	Stakeholder	Distribution System Operator	In case of the Danish pilot, ai energy will have the role of forecasting system
Flexibility management system	System	The system that predicts the aggregated demand and manages the prosumer's flexibility by generating optimal penalty signal	In case of the Danish pilot, CDK can have the role of flexibility management system

Co-funded by the European Union

Actors			
Actor Name	**Actor Type**	**Actor Description**	**Further information specific to this Use Case**
Control system (energy management system)	System	Incentive-based control and optimization algorithms	–
Forecasting systems	System	The Core System of the SEEDS FSS	In case of the Danish pilot, Enfor will have the role of providing the forecasts
Building(s)	(Sub-)System	One or more buildings that have price-responsive energy management	–

<u>Step-by-step analysis of use case</u>

Overview of scenarios

Scenario Conditions						
No	**Scenario title**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-Condition**
S01	Request Flexibility	DSO sends a day ahead demand request to the flexibility management system	DSO, flexibility management system	DSO needs flexibility in their distribution system within the next day	DSO and prosumer are connected with the flexibility management system; DSO and prosumer have an active contract for flexibility services	None
S02	Flexibility Request Evaluation	Flexibility management system checks the requests and triggers their evaluation	Flexibility management system	Fixed time deadline (e.g., each day at 8h in the morning)	Scenario S01 completed within a predefined time window (typically within this day).	None
S03	Offer Flexibility	Based on the evaluation results from S02, flexibility management	Flexibility management system	Fixed time deadline (e.g., each day at 11h in the morning)	Finished evaluation triggered in Scenario S02	None

Co-funded by the European Union

Scenario Conditions						
No	**Scenario title**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-Condition**
		system decides to make an offer or not				
S04	View and Accept or Reject Flexibility Offer	DSO checks the offer and decides to accept it or not	DSO	Fixed time deadline (e.g., each day at 12h)	Posted Flexibility management system's offer from Scenario S03	None
S05	Optimal Penalty Signal Generation	If DSO accepts the offer, it generates the optimal penalty signal for the control system	Flexibility management system	Fixed time trigger as specified in the offer (and in line with DSO's request)	Accepted the flexibility management system's offer by DSO	None
S06	Deliver Flexibility	The incentive based controller finds a control signal based on the provided penalty signal	Control system, Prosumers, Buildings	Each control iteration (e.g. every fifteen minutes)	The optimal penalty signal is generated in Scenario S05.	None
S07	View Flexibility Delivery Evaluation	Complete evaluation of the delivered flexibility is performed by DSO.	DSO, Prosumer	Flexibility delivery from scenario S06 is completed	Flexibility delivery from scenario S06 is completed	None

Steps per scenario

Scenario Name		**S01 – "Request Flexibility"**						
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
St01	Request	Request for flexibility	DSO posts request for flexibility to the flexibility management system	–	DSO	Flexibility management system	Flexibility request specification (time window, flexibility amount), Time	–

							profile of the desired demand	

Scenario Name	S02 – "Flexibility Request Evaluation"							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
St01	Request	View request for flexibility	Flexibility management system views DSO's request for flexibility	–	DSO	Flexibility management system	Flexibility request specification (time window, flexibility amount), Time profile of the desired demand	–
St02	Request	Request evaluation	Flexibility management system requests DSO for flexibility evaluation	–	Flexibility management system	DSO	Trigger flexibility request evaluation (Boolean)	–
St03	Response	Receive evaluation	Flexibility management system receives evaluation of DSO's request for flexibility	–	DSO	Flexibility management system	Flexibility request evaluation (Parameters specifying one or more options for a flexibility offer e.g complete device schedules for each offer)	–

Scenario Name	S03 – "Offer Flexibility"							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
St01	Request	Offer flexibility	Flexibility management system decides to offer (or not) one of the evaluated flexibility options	–	Flexibility management system	DSO	Decision on flexibility offer (Confirmation for one or zero flexibility offer options)	–

Co-funded by the European Union

Scenario Name	S04 – "View and Accept or Reject Flexibility Offer"							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
St01	Request	View flexibility offer	DSO views the flexibility offer	–	Flexibility management system	DSO	Flexibility offer specification (price,..)	–
St02	Request	Accept or not the flexibility offer	DSO decides to accept (or not) the flexibility offer	–	DSO	Flexibility management system	Decision on flexibility offer acceptance (Boolean)	–

Scenario Name	S05 – "Optimal Penalty Signal Generation"							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
St01	Request	Deliver penalty signal	Flexibility management system generates the optimal penalty signal using flexibility function	–	Flexibility management system	Control system	Optimal penalty signal (Time profile of penalty values)	–

Scenario Name	S06 – "Deliver Flexibility"							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
St01	Request	Deliver flexibility	Control system sends the control command to the buildings	–	Control system	Prosumer, Buildings	Control signal	–

Scenario Name	S07 – "View Flexibility Delivery Evaluation"							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
St01	Request	View flexibility delivery evaluation	DSO views flexibility delivery evaluation	–	Flexibility management system	DSO	Parameters of evaluation of the delivered flexibility (time profile)	–

3.3. USE CASES OF GREEK PILOT (GR)

3.3.1. UC – GR 1: Electrification of thermal energy demand

Description of the Use Case

Use case Identification		
ID	**Title**	**Domain**
GR1	Electrification of thermal energy demand	RES

Version Management			
Version No	**Date**	**Name of authors**	**Changes**
0.1	20.06.24	Tsompanidou Eleni (CERTH)	Initial draft outlining the main idea and scope.
02	10.12.24	Iakovos Michailidis (CERTH), Apostolos Gkountas (PTHERM)	Full details, including objectives and steps
03	01.04.24	CERTH	Revisions of the use case

Classification Information	
Pilot Involved	Greek Pilot, led by DUTh, CERTH, PTHERM
Relation to Other Use Cases	- UC – GR 3: Capturing of telemetry data
Related Innovative SEEDS solutions	- HP Parameterization Recommendation System (Task 2.4)
Assets of the UC	Heat Pump, PV

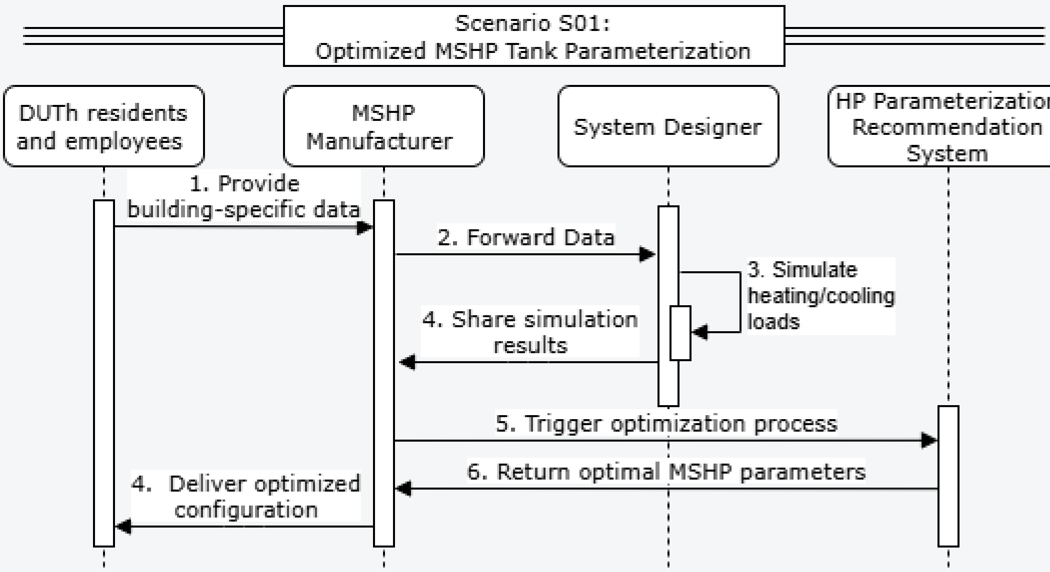
Scope and Objectives of Use Case	
Scope of the use case	The scope of this use case is to develop and demonstrate innovative and integrated solutions focused on the optimal electrification of the thermal energy demand of buildings in terms of energy efficiency, reliability and cost-effectiveness.
Objectives of the use case	• Create and implement efficient electrification solutions tailored to pilot site needs. • Optimize the heat pump system from a design parameters perspective. This enables the evaluation of different configurations

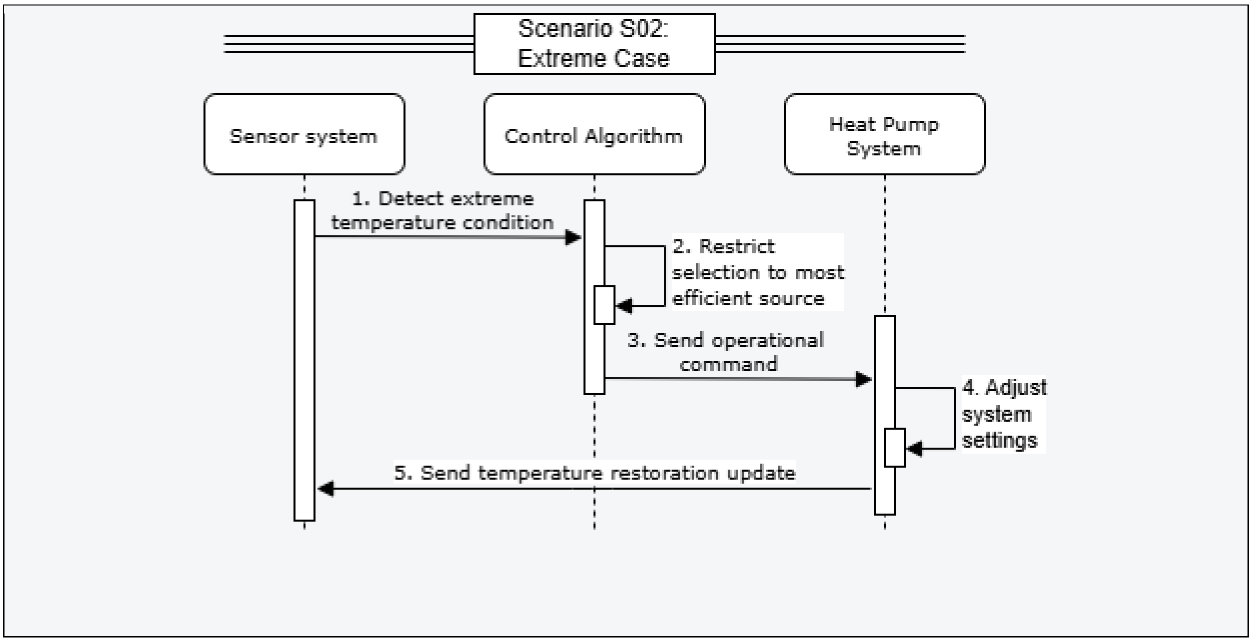
	and the identification of the most efficient parameter settings, ultimately enhancing system performance under the most demanding demand-setpoint and climate conditions that can be realistically met.
Limitations & Assumptions	• Sensors and automation systems are fully operational for optimal control. • Heat pump system is installed and available for parameterization.

Narrative of Use Case	
Short Description	This UC focuses on optimizing the electrification of thermal energy demand in buildings using an advanced, multi-source heat pump system. An HP Parameterization Recommendation System will be developed that will find the optimal design parameters of the heat pump (Task 2.4)
Complete Description	Based on the dedicated model developed by PTHERM for the Greek pilot case, the heat pump system will be optimized from a design parameters perspective, using the coefficient of performance (COP) and tank volume as key indicators. The optimization will focus on system dimensioning under varying demand-setpoint and climate conditions to identify the most efficient configuration and enhance overall system performance.

Diagrams of the UC

Sequence diagram of the use case





Technical Details of the UC

Actors			
Actor Name	**Actor Type**	**Actor Description**	**Further information specific to this Use Case**
System Designer (CERTH)	Designer	Conduct a detailed dynamic simulation analysis of the building in order to determine the heating and cooling loads. Simulation is conducted with the use of the INTEMA.building tool	Defining the heating and cooling requirements of the pilot building
HP Parameterizatio n Recommendati on System	System/ Organizati on	A system that is able to automatically decide the best parameterization of the system, anticipate system behaviour and make any final adjustments to further optimize its performance.	Electrification Solutions Parameterization
DUTh residents and employees	End-User	The students at DUTH will engage in a participatory process to co-develop a thermal management program tailored to their needs. They will provide feedback on thermal comfort preferences, participate in energy awareness initiatives, and	Technology towards electrification

Co-funded by
the European Union

Actors			
Actor Name	**Actor Type**	**Actor Description**	**Further information specific to this Use Case**
		interact with the building's automation system to optimize its operation based on real-life conditions.	
MSHP Manufactorer (PSYCTOTHERM)	System	Design and develop a heat pump system utilizing R717 (ammonia) as the working fluid to deliver both heating and cooling. This innovative heat pump will feature a multi-source configuration, optimizing energy efficiency by selecting the most suitable energy source—ambient air, solar, geothermal, or hybrid—based on operating conditions. The system will provide a heating capacity of 117 kW and a cooling capacity of 106 kW, ensuring high performance across diverse applications.	Design support tool towards sustainable building electrification solution (heating/cooling)
Sensor System	System	Detects extreme temperature conditions in the environment and sends real-time data.	
Control Algorithm	System	Receives sensor data, selects the most efficient energy source, and sends commands.	
Heat Pump	Device	Adjusts its operation based on the control algorithm's input to maintain temperature.	

Co-funded by the European Union

Step-by-step analysis of use case

Overview of scenarios

Scenario Conditions						
No	**Scenario title**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-Condition**
S01	Optimized MSHP Tank Parameterization	Automating the parameterization and performance optimization of the heat pump.	Operators of the HP, such as students or heating services	The internal temperature of the student building deviates from the set comfort range (e.g., too cold in winter or too hot in summer).	Heat pump simulation model available for system configuration and evaluation of the different trade-offs under various demand and climate conditions.	Decision that leads to the best design configuration/best parameterization of the system, further leading to the most efficient operation for the heat pump.
S02	Extreme Case (Maintaining heating or cooling in a residential student building during extreme weather conditions)	During extreme weather, when energy demand is at its peak and some energy sources may be less effective, the multi-source heat pump dynamically adjusts its operation. It prioritizes the most efficient combination of available sources—such as geothermal storage, ambient air, and solar—to maintain comfortable indoor temperatures and prevent system overload.		Outdoor temperatures reach extreme highs or lows, causing a significant deviation from the building's set comfort temperature range.	-At least one energy source remains operational despite extreme conditions. The operational mode with ambient air will be able to provide heating even when the ambient air is about -10 °C. -The heat pump's sensors are fully operational to monitor performance and environmental conditions.	The building's temperature is stabilized within the comfort range, ensuring the well-being of students. The control algorithm will be able to operate only with ambient air, if the water cannot operate in very low temperatures.

Co-funded by the European Union

Steps per scenario

Scenario Name		Optimized MSHP Tank Parameterization						
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
1	MSHP manufacturer needs to dimension the MSHP for a given building	MSHP manufacturer needs to dimension the MSHP for a given building	Request building-specific information and data	Optimization of the MSHP tank volume	Pilot building owner (DUTH)	PSYCTO (MSHP manufacturer)	Building location, building thermal demand, MSHP operational period/purposes selection (heating only, cooling only, both)	-
2			Initiate the model, adapt it to the specific buildings demand and weather conditions and run the optimization algorithm		PSYCTO (MSHP manufacturer)	Pilot building owner (DUTH)	Sizing of the MSHP tank, seasonal COP and manufacturing costs	

Scenario Name		Extreme Case Maintaining heating in a residential student building during extreme weather conditions						
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
1	Outdoor low temperatures	Heating operating only with one heat source	The heating mode will be covered totally by only ambient air as heat source. Therefore the control algorithm cannot select among the heat sources for the most efficient operation, but selects the only one available.	Heating	Sensoring system monitors and informs the user (eg DUTH heating services)	DUTH heating/technical services	Solar and geothermal waters are out of operation.	The heat pump will operate with a lower COP due to unfavorable outdoor conditions and the unavailability of other heat sources. However, the monitoring system will remain fully operational, recording the performance and all energy indicators, ensuring this data is accessible to all stakeholders.

3.3.2. UC – GR 2: Minimization of Life Cycle Environmental Impact through Circular Design Principles

Description of the Use Case

Use case Identification		
ID	**Title**	**Domain**
GR2	Minimization of Life Cycle Environmental Impact through Circular Design Principles	Sustainability, Circular Economy, Environmental Impact Management

Version Management			
Version No	**Date**	**Name of authors**	**Changes**
01	11.12.24	Nikolaos Rapkos (RENEL)	Complete Use Case Description
02	02.02.24	Pantelis Botsaris (DUTh)	Use case Review
03	12.03.25	Evangelia Rigati (RENEL)	Additional Information Added
03	01.04.25	Eleni Tsompanidou (CERTH)	Revisions of the use case

Classification Information	
Pilot Involved	Greek Pilot, led by DUTh, Certh, Renel
Relation to Other Use Cases	N/A
Related Innovative SEEDS solutions	N/A
Assets of the UC	PV system and Heat pump powered by the geothermal and solar thermal field

Scope and Objectives of Use Case	
Scope of the use case	This use case focuses on the development and life-cycle management of a ground-based bifacial photovoltaic system combined with an innovative reflection tracking system, used to optimize solar capture and supply clean electricity to a heat pump. The project integrates circular design principles to minimize the environmental footprint at all life cycle stages—from material sourcing to decommissioning.

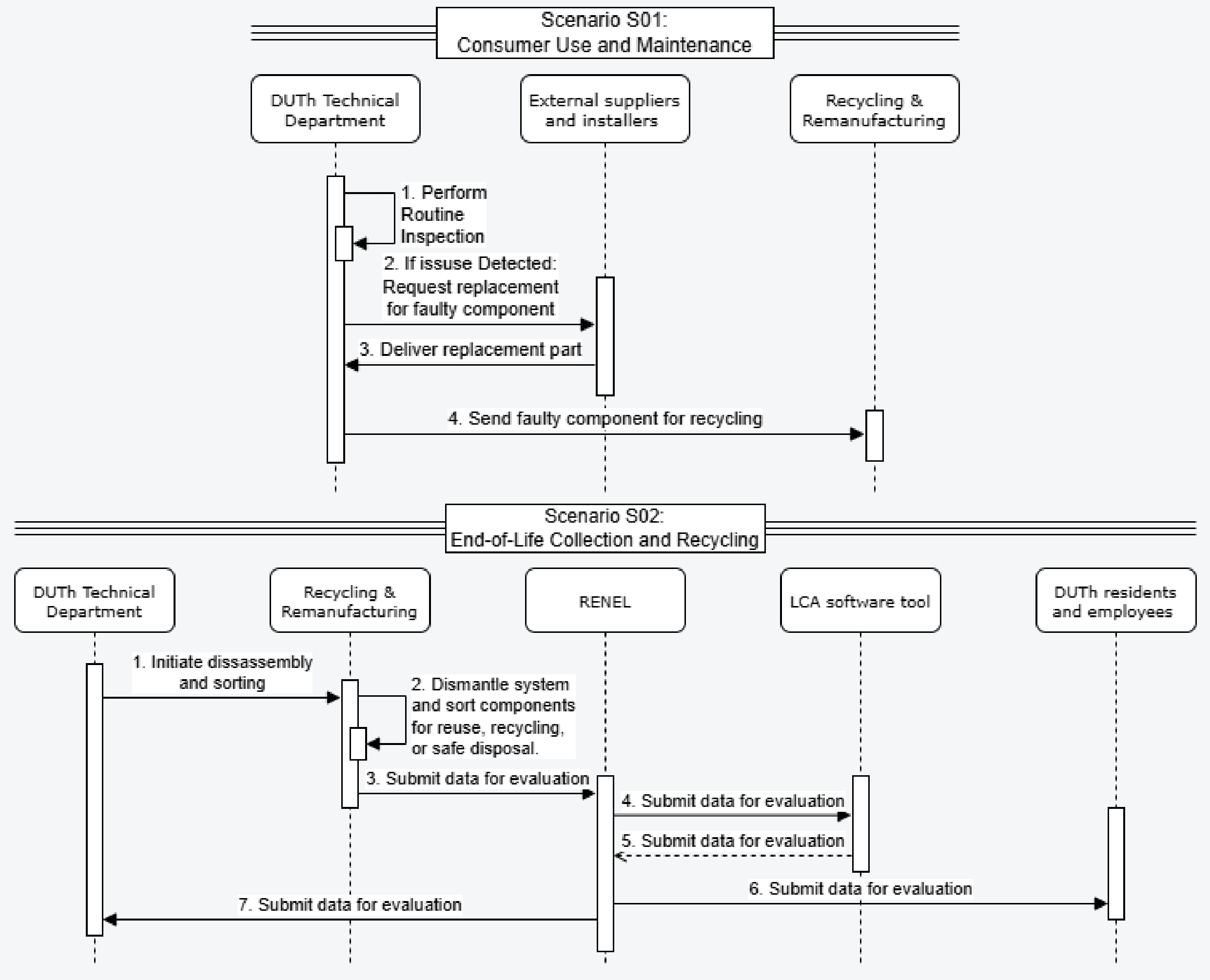
Co-funded by the European Union

Objectives of the use case	• Apply circular design principles to all components of the PV-reflection system and its interface with the heat pump. • Select recyclable and low-impact materials for the panel frame, reflective system and support infrastructure, such as aluminium. • Measure and reduce the environmental impacts using life cycle assessment (LCA) tools.
Limitations & Assumptions	• The reflection system and the PV support structure should allow easy disassembly • Data for the LCA are gathered from the pilot installation at DUTh campus • Recycling capacity is relevant to aluminum, plastic film, and electronic components • Reuse potential is available for support structures and mechanical actuators

Narrative of Use Case	
Short Description	This use case focuses on how the implementation of a photovoltaic-reflection energy system can be optimized to minimize life cycle environmental impacts. Circular design is embedded at each phase: sourcing, production, operation, and end-of-life.
Complete Description	The PV-reflection system consists of bifacial solar modules mounted on the ground combined with a reflection system that will be placed behind them. The reflection system maximizes rear-side irradiance and energy yield. The generated electricity will feed a multi-source heat pump to cover part of its needs, reducing fossil fuel dependency. The design process favor recyclable materials, modularity for part replacement and minimal embedded emissions. LCA tools will be employed throughout the project to inform design adjustments and ensure circularity. The end-users will be properly trained towards sustainable end-of-life management.

Diagrams of the UC

Sequence diagram of the use case



Technical Details of the UC

Actors			
Actor Name	**Actor Type**	**Actor Description**	**Further information specific to this Use Case**
DUTh residents and employees	End-User	Individuals that use the system.	-
DUTh technical department team	Maintenance	Individuals that maintain the system.	-
External suppliers and installers	Installation work, Supply	Technical experts responsible for the procurement and installation phases of the systems' components and the supply of components.	
Recycling and Remanufacturing	Service Provider	Organizations that handle the end-of-life collection, recycling, and remanufacturing.	Essential for returning materials to the supply chain for reuse.
Municipality	Authority	Municipality's alignment with regulations that set goals for sustainability.	Ensures compliance with circular economy and sustainability regulations.
LCA software tool	Digital Tool	It will be utilised to assess the environmental impact of the PV-reflection system across all life cycle stages, guiding design improvements and end-of-life planning	
RENEL	Coordinator	Oversees design, life-cycle analysis, and sustainability strategy for the system.	

Step-by-step analysis of use case

Overview of scenarios

Scenario Conditions						
No	**Scenario title**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-Condition**
S01	Consumer Use and Maintenance	Regular inspections and maintenance actions ensure high performance. Modular components are replaced when needed to extend system lifetime.	DUTh's Technical Department team	Product usage and scheduled check or performance anomaly detected	System is operational with accessible and replaceable components	System is used for a longer duration and with reduced environmental impact
S02	End-of-Life Collection and Recycling	End-of-life products are collected for recycling or remanufacturing into new products, reducing waste.	Recycling & Remanufacturing service provider	Product reaches end of life	Product has been designed for disassembly and recycling	The system components are successfully recycled or remanufactured and environmental impact is minimized

Co-funded by
the European Union

Steps per scenario

Scenario Name		Consumer Use and Maintenance						
Step No.	Event	Name of Process/ Activity	Description of Process/ Activity	Service	Information Producer (Actor)	Information Receiver (Actor)	Information exchanged (IDs)	Requirements, R-ID
St1	Scheduled maintenance	Routine Inspection	Inspection of the PV-reflector system by DUTH's technical department to detect performance drops, wear, or damage.	Maintenance	DUTH's Technical Department	DUTH's Technical Department	Product usage data and inspection log	System manuals and maintenance instructions.
St2	Detected issue	Replacement of the faulty component	Replace damaged or degraded components to restore full system functionality.	Repair service	DUTH's Technical Department, External suppliers and installers	DUTH's Technical Department, Recycling and Remanufacturing	Repair report	System manuals and maintenance instructions. Availability of repair services and spare parts

Scenario Name		End-of-Life Collection and Recycling						
Step No.	Event	Name of Process/ Activity	Description of Process/ Activity	Service	Information Producer (Actor)	Information Receiver (Actor)	Information exchanged (IDs)	Requirements, R-ID
St1	End-of-life products are collected for recycling or remanufacturing	Disassembly and Material Sorting	Dismantle system and sort components for reuse, recycling, or safe disposal.	End-of-Life Service	RENEL, Recycling Provider	DUTH, local recycling company	Disassembly Plan	Collection infrastructure.
St2	Collected products are recycled or repurposed into new products or materials- Final review	LCA Impact Assessment	Perform LCA to evaluate environmental benefits and savings achieved through circular design.	Sustainability Report	RENEL	DUTH, resident, all relevant stakeholders	LCA report	LCA software tool

Co-funded by the European Union

3.3.3. UC – GR 3: Capturing of telemetry data

Description of the Use Case

Use case Identification		
ID	**Title**	**Domain**
GR3	Capturing of telemetry data	Data Management, Visualization

Version Management			
Version No	**Date**	**Name of authors**	**Changes**
01	20.06.24	Tsompanidou Eleni (CERTH)	Draft definition of the use case
02	03.12.24	Achilleas Andronikos (CERTH)	Filling the contents of the use case for the Greek Pilot case
03	05.12.24	PantelisBotsaris (DUTh)	Review of the use case
04	07.12.24	Achilleas Andronikos (CERTH)	Revisions of the use case
05	03.04.24	CERTH	Revisions of the use case

Classification Information	
Pilot Involved	Greek Pilot, led by DUTh
Relation to Other Use Cases	- GR-UC1: Electrification of thermal energy demand - GR-UC4: Active control of electrification systems - GR-UC5: Predictive Maintenance of Heat Pump and PV Systems - GR-UC6: Participation in Demand Response Schemes
Related Innovative SEEDS solutions	– FIWARE-based interoperable facility management platform – Protocol inclusive gateway agents – Data quality assurance mechanism – Visual analytics engine for users enhanced situation awareness

Co-funded by the European Union

Assets of the UC	Multi-source HP, bi-facial PV, PLC, EV chargers, sensors on dorm rooms (20 out of 68 rooms) and central measuring sensors located in the building's basement.

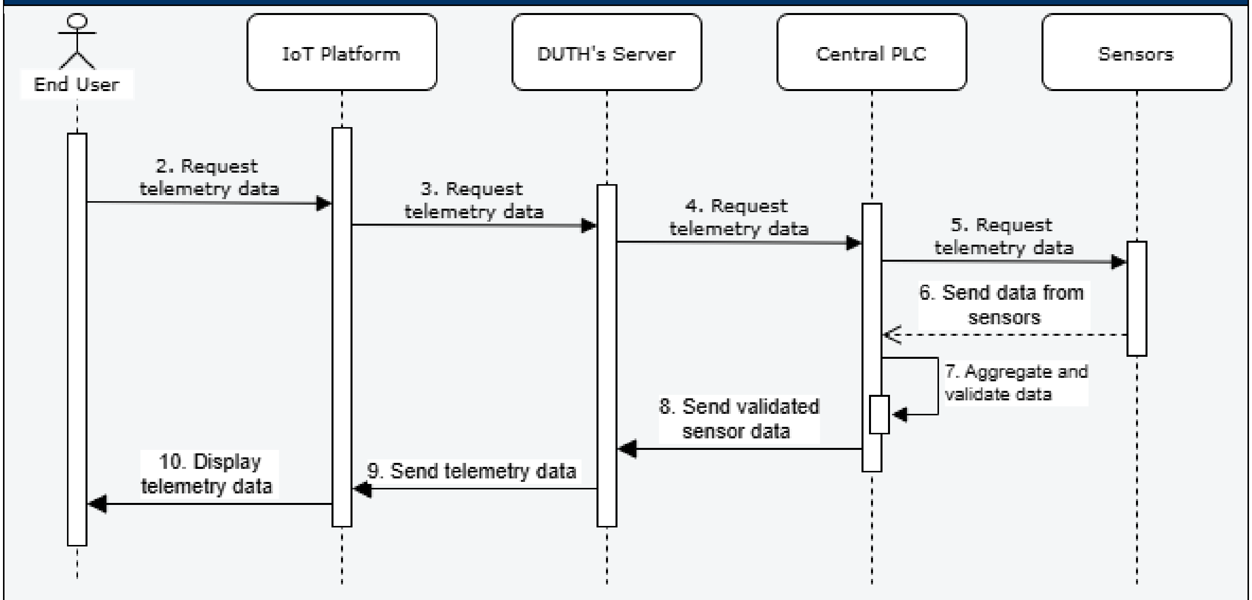
Scope and Objectives of Use Case	
Scope of the use case	The scope of this use case involves ensuring that data management and pre-processing mechanisms for a smart IoT platform in facility management adhere to FAIR principles. This includes developing tools for representing heterogeneous data from internal sensors in smart appliances, existing building systems, open API web sources (such as weather and electricity prices), and automation devices connected to electrification systems.
Objectives of the use case	• Integration of sensory data collected from 20 (out of 68) student dorm rooms. • Interoperable smart facility management platform. • Automated IoT ecosystem with seamless operation and maintenance services. • Secure and reliable monitoring, trend analysis and assessment tools that provide insights towards more optimizations
Limitations & Assumptions	• The system assumes proper sensor installation and remote monitoring and control access of the equipment planned to be installed within the SEEDS project for the Greek pilot site. • Data integrity is ensured via the PLC and IoT platform • Real-time updates may depend on network stability • Integration of the IoT platform assumes compliance with all regulations (eg. GDPR)

Narrative of Use Case	
Short Description	A middleware platform is developed that permits the seamless data transfer between the smart IoT devices. It focuses on handling various open APIs and protocols, using standardized semantic models for electrification systems and devices to enable effective reasoning and context awareness, and incorporating data quality and curation mechanisms to ensure reliable AI services. This approach allows for the effective application and integration of data-driven building optimization and control schemes, accommodating varying levels of observability.
Complete Description	This use case supports end-to-end telemetry data collection from room-level and building-level sensors, energy infrastructure and other data sources. A

Narrative of Use Case	
	central gateway (PLC) into a dedicated server (DUTH) is utilized for collecting and aggregating information from multiple dormitory rooms. The gateway serves as primary interface between sensors and the CERTH IoT platform. The platform provides real-time data collection and monitoring of different data sources under a unified approach. Features of the IoT platform includes: • FIWARE-based interoperable facility management platform • Protocol inclusive gateway agents • Data quality assurance mechanism • Visual analytics engine for users enhanced situation awareness

Diagrams of the UC

Sequence diagram of the use case



Technical Details of the UC

Actors			
Actor Name	**Actor Type**	**Actor Description**	**Further information specific to this Use Case**
Sensors	Device	Collect telemetry data (e.g temperature, CO2) from the dorm rooms	Installed in each room (20 rooms out of 68)
Central PLC	System	Aggregates data from sensors and transmits it to DUTH server.	Must support IoT connectivity protocols (eg. MQTT)
DUTH's Server	System	Data from all the SEEDS equipment of the pilot (building rooms, building basement, energy assets) are transmitted into the DUTH server, which then forwards all the generated data to the CERTH IoT platform.	N/A
Energy Assets	Device	Includes all the available energy assets of the Greek pilot site (multi-source HP, bi-facial PVs, EV chargers)	N/A
IoT platform (and Visual Analytics Engine)	Application	Receives and visualizes data provided by DUTH's server. Provides analytics dashboards	Integration APIs provided by CERTH
Building Manager/Operator	User	Monitors building data and acts on alerts/reports.	N/A

Co-funded by
the European Union

Step-by-step analysis of use case

Overview of scenarios

Scenario Conditions						
No	**Scenario title**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-Condition**
S01	Visualization of telemetry data	Actor (building manager) interacts with the visualization software (IoT platform)	IoT platform	Request access to facility monitoring dashboards.	IoT platform having remote access to all sensory data and energy assets monitoring capabilities.	Dashboards and analytics provided to building managers.
S02	Historic data retrieval for AI tools (developed under WP4 and WP5)	Automated service-to-service data exchange between the IoT platform and other AI tools (developed under other WPs)	IoT platform	Request real-time or historic data from an integrated asset.	IoT platform having remote access to all sensory data and energy assets monitoring capabilities.	Return the requested data in a time series format

Steps per scenario

Scenario Name:	Visualization of telemetry data							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
St1	Scheduled measurement interval	Data Collection	Sensors in each dorm room/basement collects data (eg. Temperature, humidity)	Measurement	Sensor	Central PLC	Raw sensor data	R-01: The Sensors are installed and are operational, R-02: Regular data collection intervals have been set
St2	Completion of data collection	Data aggregation	DUTh's server aggregates the data received from the sensors and performs basic validation checks.	Data Processing	Central PLC	DUTh's server	Aggregated data	R-03: The DUTh's server must support IoT communication protocols
3	Completion of data collection from the energy asset of the pilot (e.g. PV system, HP system)	Data aggregation	DUTh's server aggregates the data received from the energy assets and performs basic validation checks.	Data Processing	Energy Assets	DUTh's server	Aggregated data	R-04: The energy assets must provide remote monitoring capabilities

Co-funded by the European Union

Scenario Name:	Visualization of telemetry data							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
St3	Monitor of the energy assets	Data Collection	The IoT platform receives data in a regular basis from all the other available energy assets or sensor of the pilot (eg. PV system, HP system, room sensors) via communication with the DUTh server and integrates them with data coming from other data sources.	Data Processing	DUTh's server	IoT platform	Aggregated data	R-05: Validation of incoming data
St4	Visualization of data	Visualization	CERTH IoT Platform visualizes aggregated real-time and historic data on dashboards and generates analytics insights.	Data Visualization and analytics	IoT platform	Building managers	Data visualizations	R-06: Dashboards accessible to building managers

Scenario Name:		Historic data retrieval						
Step No.	Event	Name of Process / Activity	Description of Process/ Activity	Service	Information Producer (Actor)	Information Receiver (Actor)	Information exchanged (IDs)	Requirements, R-ID
1	Request of data from the IoT platform	Data Request	A service/tool wants to consume data from the IoT platform	Data access	AI-driven tools	IoT platform	Request to IoT platform	R-07: All external services must use authenticated requests, R-08: All services must integrate with the IoT platform APIs
2	Processing the request	Data aggregation	The IoT platform aggregates historic available data within the platform with real-time data based on the request query.	Data Processing	IoT platform	IoT platform	Aggregated data	R-08: The IoT platform should provide advanced querying capabilities
3	Execution of the data request	Data Collection	The external tool/service receives the data from the IoT platform	Data Processing	IoT platform	AI-driven tools	Aggregated data	R-04: The energy assets must provide remote monitoring capabilities, R-05: Validation of incoming data

3.3.4. UC – GR 4: Active control of electrification systems

Description of the Use Case

Use case Identification		
ID	**Title**	**Domain**
GR4	Active control of electrification systems	Integrated Energy Systems

Version Management			
Version No	**Date**	**Name of authors**	**Changes**
01	14.11.24	RENEL	Use Case Description
02	18.12.24	Pantelis Botsaris (DUTH)	Review
03	15.02.25	George Karatzinis, Kyriaki Fanaridou (CERTH)	Additional Information Added
04	01.04.25	Tsompanidou Eleni (CERTH)	Revisions of the use case

Classification Information	
Pilot Involved	Greek Pilot, led by PTHERM, DUTh, Certh, Renel
Relation to Other Use Cases	- UC – GR 3: Capturing of telemetry data
Related Innovative SEEDS solutions	- Smart Modulation Control for Multi-Source HPs (T4.1.1 - Greek Pilot) - Smart Tracking Control for Reflector Systems (T4.1.2 - Greek Pilot) - Smart Thermal Comfort and Energy Consumption Manager (T4.2 - Greek Pilot)
Assets of the UC	PV system, heat pump, solar thermal, Geothermal system

Scope and Objectives of Use Case	
Scope of the use case	This use case focuses on intelligent control mechanisms for heat pump modulation, thermostat optimization and PV reflector optimizations, in order to enhance system performance and reliability.

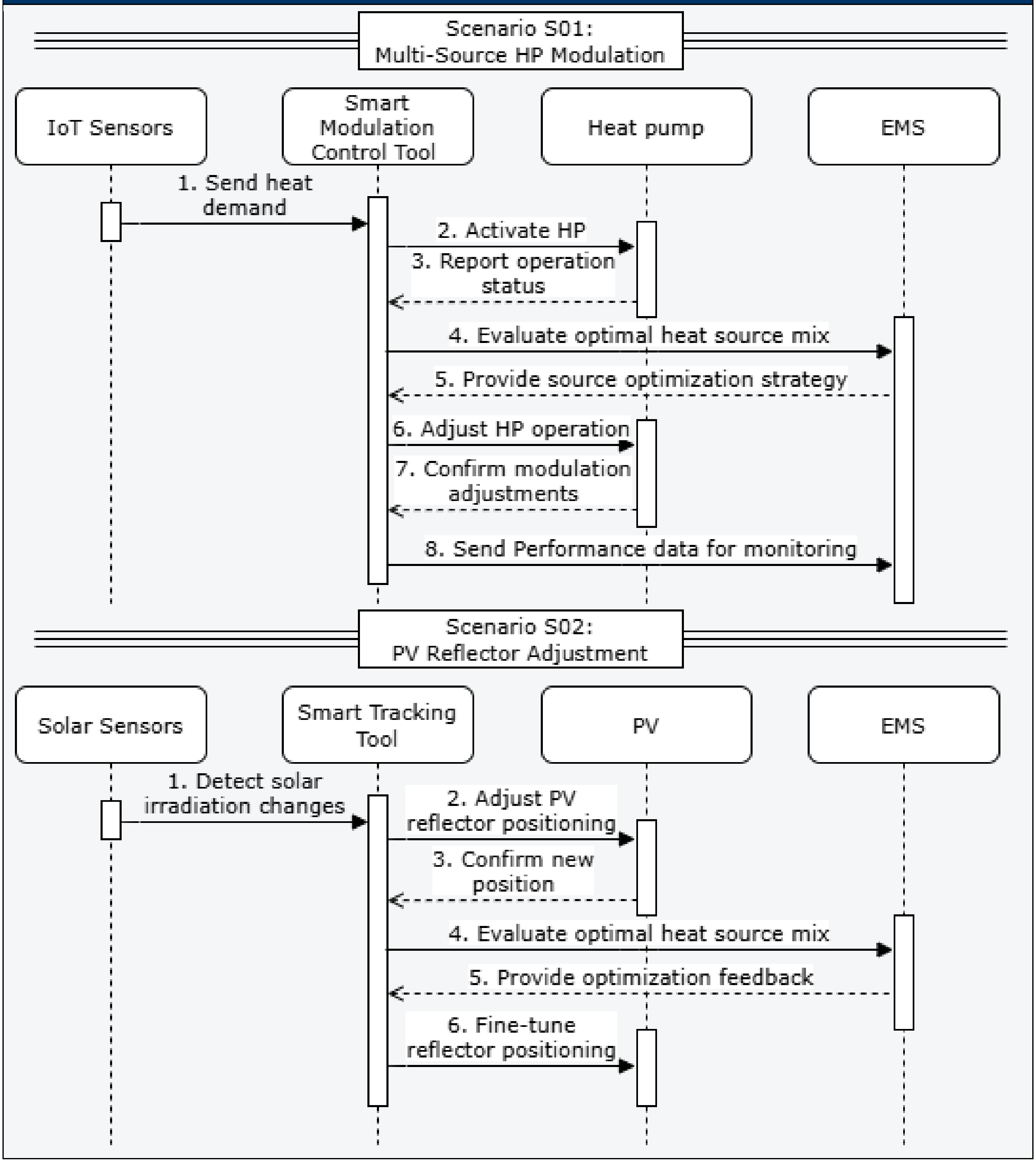
Co-funded by the European Union

Objectives of the use case	• Ensure the system optimally mixes heat sources to maintain user comfort, improve heat pump performance, and ensure environmental efficiency. • Maximize energy yield and efficiency through smart tracking tool for PV reflector system, considering sun position and externalities. • Control framework for thermostat setpoint adjustment that ensures thermal comfort for building occupants while minimizing energy consumption. • Enhance performance through real-time control, and adaptive management for MSHP, PV reflector system, FCU.
Limitations & Assumptions	• Real-time energy data is available for decision-making. • IoT-enabled sensors and smart control systems are available.

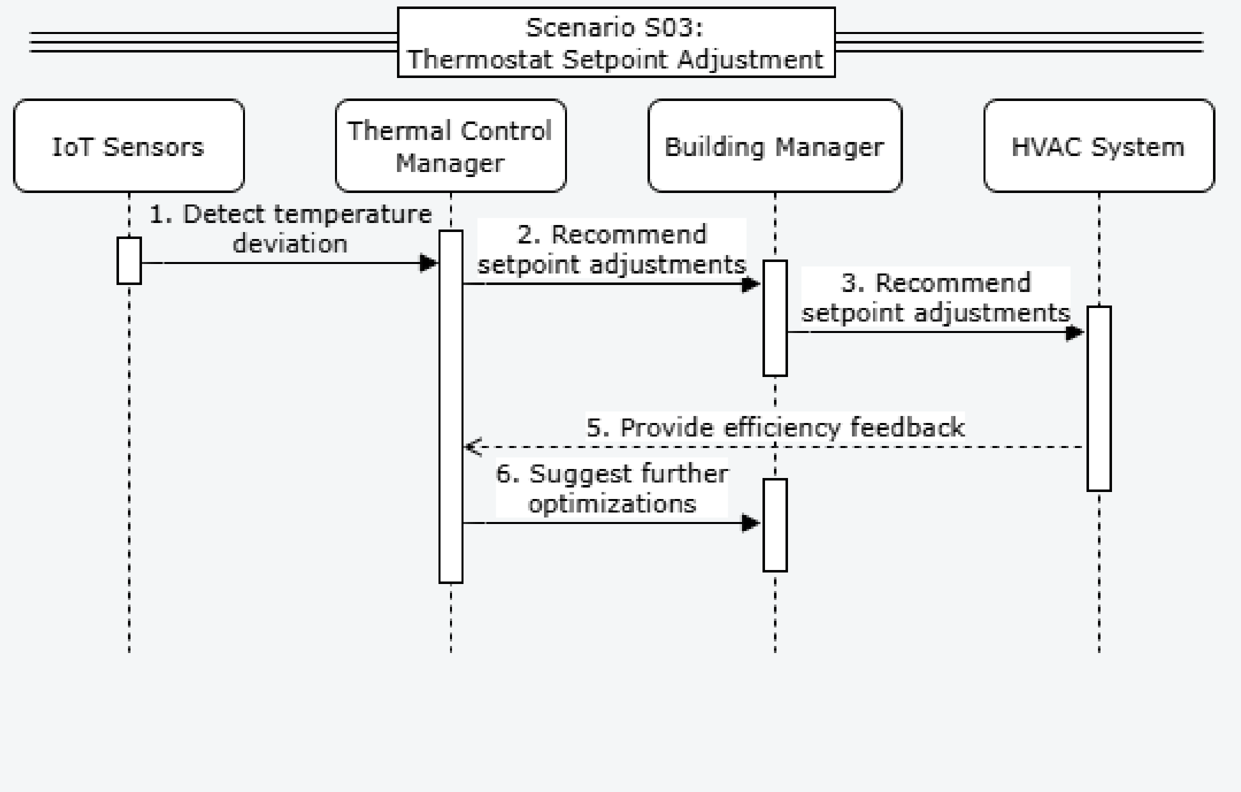
Narrative of Use Case	
Short Description	The use case addresses the intelligent control of Heat Pump modulation, PV reflector tracking systems, and thermostats to enhance operational efficiency, user comfort, and energy savings.
Complete Description	The use case involves the deployment of advanced control mechanisms to optimize the performance of thermal and photovoltaic (PV) systems. More specifically, it includes dynamic modulation of multi-source heat pump to optimize energy use and ensure thermal comfort. Smart tracking tools for PV reflectors maximize solar energy yield by dynamically adjusting their positioning. Thermostat setpoint adjustments are managed in real-time to balance energy consumption and indoor comfort. will allow operators to monitor fluctuations in supply and demand efficiently. Advanced control frameworks facilitate load shifting, maximize renewable energy utilization, and ensure seamless coordination between energy generation and consumption. The policies will also aim to meet environmental goals by prioritizing the use of renewable energy sources and enhancing stability through flexibility mechanisms.

<u>**Diagrams of the UC**</u>

Sequence diagram of the use case



Sequence diagram of the use case



Technical Details of the UC

Actors			
Actor Name	**Actor Type**	**Actor Description**	**Further information specific to this Use Case**
DUTh residents and employees	End-User	Consumers who use the system (e.g., through PV).	Mainly residential consumers.
IoT Sensors	Device	Monitor temperature, occupancy, HVAC performance, solar radiation	Provide real-time data
Smart Modulation Control Tool	System	Dynamically controls heat pump operation	Optimizes energy efficiency and thermal comfort
Smart Tracking Tool	System	Adjusts the positioning of bifacial PV reflectors	Enhances the efficiency of PV systems
Thermal Comfort Managing Tool	System	Adjusts thermostat setpoints	Adjusts thermostat setpoints
Building Manager	End-User	Oversees system operation and approves control decisions when needed.	Oversees thermostat adjustments
Energy Management System (EMS)	System	Control system that allows the centralized management of a building's systems.	

Co-funded by
the European Union

Step-by-step analysis of use case

Overview of scenarios

Scenario Conditions						
No	**Scenario title**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-Condition**
S01	Multi-Source Heat Pump Modulation	Modulation of heat pump operation to optimize energy efficiency, comfort, and source selection.	Smart Modulation Control Tool	-	Real-time data from energy sources and heat pump and remote control setting	Heat pump operates with optimal source mix.
S02	PV Reflector Adjustment	Dynamic adjustment of bifacial PV reflector positioning to maximize energy yield.	Smart Tracking Tool	Solar irradiation change detected	Availability of data, access and monitoring of data and actions remotely and remote control of PV reflector adjustment	PV energy produced is maximized
S03	Thermostat Setpoint Adjustment for Comfort and Energy Efficiency	Real-time adjustment of thermostat setpoints in individual rooms to maintain thermal comfort and minimize energy usage.	Thermal Comfort Managing Tool	A deviation from desired indoor temperature or occupancy changes in one or more rooms.	Availability of real-time indoor temperature and occupancy data for the building.	Thermal comfort restored/sustained and energy consumption optimized by adjusting thermostat setpoints.

Steps per scenario

Scenario Name		Multi-Source Heat Pump Modulation						
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
St1	Heat Demand Detected	Heating Activation	The modulation tool detects heating demand and activates the heat pump.	Heating control	Temperature/occupancy sensors	Smart Modulation Control Tool	Heat demand signal (INF 4.1)	Real-time sensor /controller integration.
St2	Source Optimization	The tool evaluates the availability, cost, and environmental impact of heat sources.	The system adjusts energy flows by controlling demand response or adjusting generation schedules	Energy Management	Source monitoring system	Smart Modulation Control Tool	Source data (INF 4.2)	Monitoring system for energy sources.
St3	Modulation Adjustment	Source-Based Modulation	The tool adjusts heat pump operation to optimize energy efficiency and comfort.	Heating/Cooling Control	Smart Modulation Control Tool	Heat Pump	Modulation instructions (INF 4.3)	Heat pump compatible with modulation inputs.
St4	Feedback Loop	Performance Monitoring	The system collects performance data to refine modulation strategies.	Monitoring	Smart Modulation Control Tool	Energy Management System	Performance data (INF 4.4)	Data collection infrastructure.,

Scenario Name		PV Reflector Adjustment						
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
St1	Change in irradiation	Irradiation Monitoring	The tracking tool detects changes in solar irradiation levels.	Solar Tracking	Solar sensors	Smart Tracking Tool	Irradiation data (INF 5.1)	Solar sensor integration.

Co-funded by the European Union

St2	Reflector adjustment	Position/angle Optimization	The tool adjusts PV reflector positioning to maximize solar energy capture.	PV Optimization	Smart Tracking Tool	PV Reflectors	Position adjustment signal (INF 5.2)	Reflectors compatible with tool inputs.
St3	Energy Yield Monitoring	Performance Feedback	The system monitors PV energy yield to refine reflector control strategies.	Monitoring	Smart Tracking Tool	Energy Management System	Yield data (INF 5.3)	Real-time PV yield monitoring.

Scenario Name	**Thermostat Setpoint Adjustment for Comfort and Energy Efficiency**							
Step No.	**Event**	**Name of Process / Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
St1	Temperature Deviation Detected	Condition Monitoring	System detects a deviation from the desired room temperature or comfort bounds.	Monitoring Service	Temperature/occupancy indoor sensors	Thermal Comfort Managing Tool	Indoor temperature data (INF 6.1)	Real-time sensor integration.
St2	Setpoint Adjusted Evaluated	Control Policy Evaluation	System evaluates the optimal thermostat setpoint adjustments based on comfort and energy efficiency.	Control Optimization	Thermal Comfort Managing Tool	Building Manager	Adjusted thermostat recommendations (INF 6.2)	Black-box MPC framework active.
St3	Adjustments Implemented	Thermostat Setpoint Adjustment	Thermostat settings are updated in the affected room(s) to	Heating/Cooling Control	Thermal Comfort Managing Tool	Thermostat	Adjusted setpoint values (INF 6.3)	Thermostats responsive to control inputs.

Co-funded by the European Union

			restore comfort.					
St4	Feedback Loop	Impact Monitoring	System collects data on energy consumption and restored comfort levels for further optimization.	Monitoring and Feedback	HVAC Sensors	Thermal Comfort Managing Tool	Performance data (INF 6.4)	Reliable monitoring and feedback systems.

Co-funded by the European Union

3.3.5. UC – GR 5: Predictive Maintenance of Heat Pump and PV Systems

Description of the Use Case

Use case Identification		
ID	**Title**	**Domain**
GR5	Predictive Maintenance of Heat Pump and PV Systems	Integrated Energy Systems

Version Management			
Version No	**Date**	**Name of authors**	**Changes**
01	14.11.24	RENEL	Complete Use Case Description
02	13.12.24	Pantelis Botsaris (DUTH)	Review
03	20.02.25	George Karatzinis, Kyriaki Fanaridou (CERTH)	Additional Information Added
04	01.04.24	Tsompanidou Eleni (CERTH)	Revisions of the use case

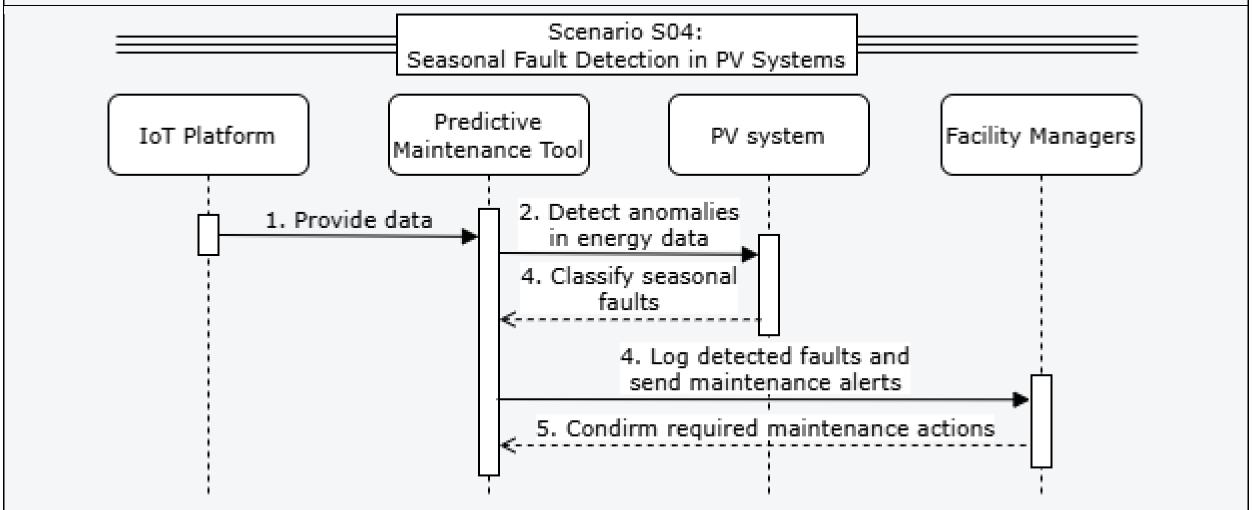
Classification Information	
Pilot Involved	Greek Pilot, led by PTHERM, DUTh, Certh, Renel
Relation to Other Use Cases	- UC – GR 3: Capturing of telemetry data
Related Innovative SEEDS solutions	- Predictive Maintenance Service dedicated to electrification systems (T4.4.1 - Greek Pilot)
Assets of the UC	PV system and Heat pump

Scope and Objectives of Use Case	
Scope of the use case	This use case focuses on intelligent control mechanisms for heat pump modulation, thermostat optimization and PV reflector, and predictive maintenance of energy assets (PVs, Heat Pump)., in order to enhance system performance and reliability
Objectives of the use case	• Ensure reliable operation of heat pump and PV systems through predictive maintenance, enabling long operational life and minimal disruptions.
Limitations & Assumptions	• IoT-enabled sensors and smart control systems are available.

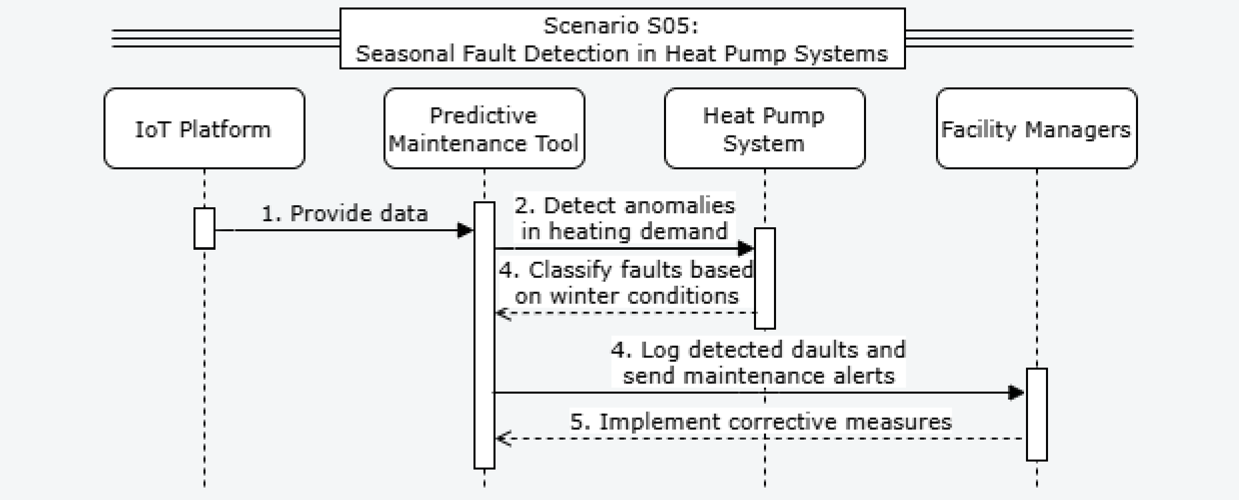
Narrative of Use Case	
Short Description	This use case integrates predictive maintenance techniques to detect potential faults in energy assets, ensuring long-term system reliability and performance.
Complete Description	The use case addresses the predictive maintenance of Heat Pump and photovoltaic (PV) systems to enhance system performance and energy efficiency. Furthermore, predictive maintenance techniques utilize real-time and synthetic data to detect and classify faults in heat pump and PVystems.

Diagrams of the UC

Sequence diagram of the use case



Sequence diagram of the use case



Technical Details of the UC

Actors			
Actor Name	**Actor Type**	**Actor Description**	**Further information specific to this Use Case**
DUTh residents and employees	End-User	Consumers who use the system (e.g., through PV).	Mainly residential consumers.
DUTh, CERTH, PSYCTO, RENEL employees	Research	Research on innovative energy generation-demand systems.	Important for all partners to improve know-how in such systems.
Municipality	Beneficiary	The region benefits from energy advancements.	Achieves sustainability goals.
IoT Sensors	Device	Monitor temperature, occupancy, HVAC performance, solar radiation	Provide real-time data
Predictive Maintenance Tool	System	Analyzes data and detects faults in heat pump and PV systems	Uses data for predictive maintenance
Facility managers	End-User	Oversee system operation.	

Co-funded by the European Union

Step-by-step analysis of use case

Overview of scenarios

Scenario Conditions						
No	**Scenario title**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-Condition**
S01	Seasonal short-term fault detection in PV systems	During winter the tool detects PV malfunctions in PV systems using hourly data, analyzing the impact of lower temperatures and reduced irradiance. In summer the scenario will evaluate the fault detection under higher ambient temperatures and irradiance. Fault scenarios are emulated by adding noise to real data.	Predictive maintenance tool (T4.4.1)	Hourly energy data shows anomalies.	Synthetic data from PV systems including ambient temperature and irradiance containing faults are available. Real-time sensory data from the IoT platform are accessible for fault creation and testing.	Faulty behaviors are detected and classified, and results are logged to understand and address seasonal challenges.
S02	Winter Short-Term Fault Detection in Heat Pump Systems	During winter the tool monitors hourly data to assess fault detection accuracy under low temperatures and high heating demands. Since no actual breakdowns are expected, noisy signals will be imposed on the input data to emulate faults.	Predictive maintenance tool (T4.4.1)	Anomalies detected in energy consumption patterns.	Synthetic data from HP systems containing faults are available. Real-time sensory data from the IoT platform are accessible for fault creation and testing.	Faulty behaviors are detected and classified, and results are logged to understand and address possible winter challenges.

Steps per scenario

Scenario Name	Seasonal short-term fault detection in PV systems							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
St1	Fault Emulation	Synthetic simulation of faults	Noisy signals are added to real-life input data to emulate faults and validate detection mechanisms for different seasonal conditions.	Fault emulation	IoT Platform (Greek Pilot - DUTH)	Predictive Maintenance Tool	Fault-emulated data (INF 7.1)	IoT platform data are available.
St2	Fault Detection and Classification	Fault classification	The predictive maintenance tool monitors hourly energy data for unusual patterns and identifies what kind of faults are happening considering the different effects of winter and summer conditions.	Fault Detection	Predictive Maintenance Tool	Predictive Maintenance Tool	Fault type and anomalies (INF 7.2)	Hourly energy data that shows faults
St3	Insights Logging	Performance Feedback	The tool saves details about detected faults and seasonal trends, helping operators understand recurring problems and plan better maintenance.	Monitoring	Predictive Maintenance tool	Facility managers and Maintenance Team (DUTH)	Seasonal insights log (INF 7.3)	Logging system for storing insights.

Co-funded by the European Union

Scenario Name		Winter Short-Term Fault Detection in Heat Pump Systems						
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
1	Fault Emulation	Synthetic simulation of faults	Noisy signals are added to real-life input data to emulate faulty behaviors in heat pumps since no faults are expected during testing period.	Fault emulation	IoT Platform (Greek Pilot - DUTH)	Predictive Maintenance Tool	Fault-emulated data (INF 7.1)	IoT platform data are available.
2	Fault Detection and Classification	Fault classification	The predictive maintenance tool monitors hourly energy consumption data for unusual patterns and identifies fault types based on winter-specific conditions like low temperatures and high heating demand.	Fault Detection	Predictive Maintenance Tool	Predictive Maintenance Tool	Fault type and anomalies (INF 7.2)	Hourly energy data that shows faults
3	Insights Logging	Performance Feedback	The tool saves details about detected faults and winter trends, helping operators understand recurring problems and plan better maintenance.	Monitoring	Predictive Maintenance tool	Facility managers and Maintenance Team (DUTH)	Seasonal insights log (INF 7.3)	Logging system for storing insights.

Co-funded by the European Union

3.3.6. UC – GR 6: Participation in Demand Response Schemes

Description of the Use Case

Use case Identification		
ID	**Title**	**Domain**
GR6	Participation in Demand Response Schemes	DER, Flexibility

Version Management			
Version No	**Date**	**Name of authors**	**Changes**
01	20.06.24	Tsompanidou Eleni (CERTH)	Initial draft outlining the main idea and scope.
02	10.12.2024	Iakovos Michailidis (CERTH)	Additional Information Added
03	04.04.2025	Tsompanidou Eleni (CERTH)	Revisions of the use case

Classification Information	
Pilot Involved	Greek Pilot, led by DUTh, CERTH
Relation to Other Use Cases	- UC – GR 3: Capturing of telemetry data
Related Innovative SEEDS solutions	1. Baseline Consumption Simulation Tool (T2.3 – T5.1 Greek Pilot) 2. Flexibility Forecasting Module (T5.1-Greek Pilot) 3. Demand Reshaping tool (T5.2-Greek Pilot) 4. Grid-Support-Manager (WP5 – Greek Pilot)
Assets of the UC	Multi-source HP, bi-facial PV, PLC, EV chargers, sensors on dorm rooms (20 out of 68 rooms) and central measuring sensors located in the building's basement.

Co-funded by the European Union

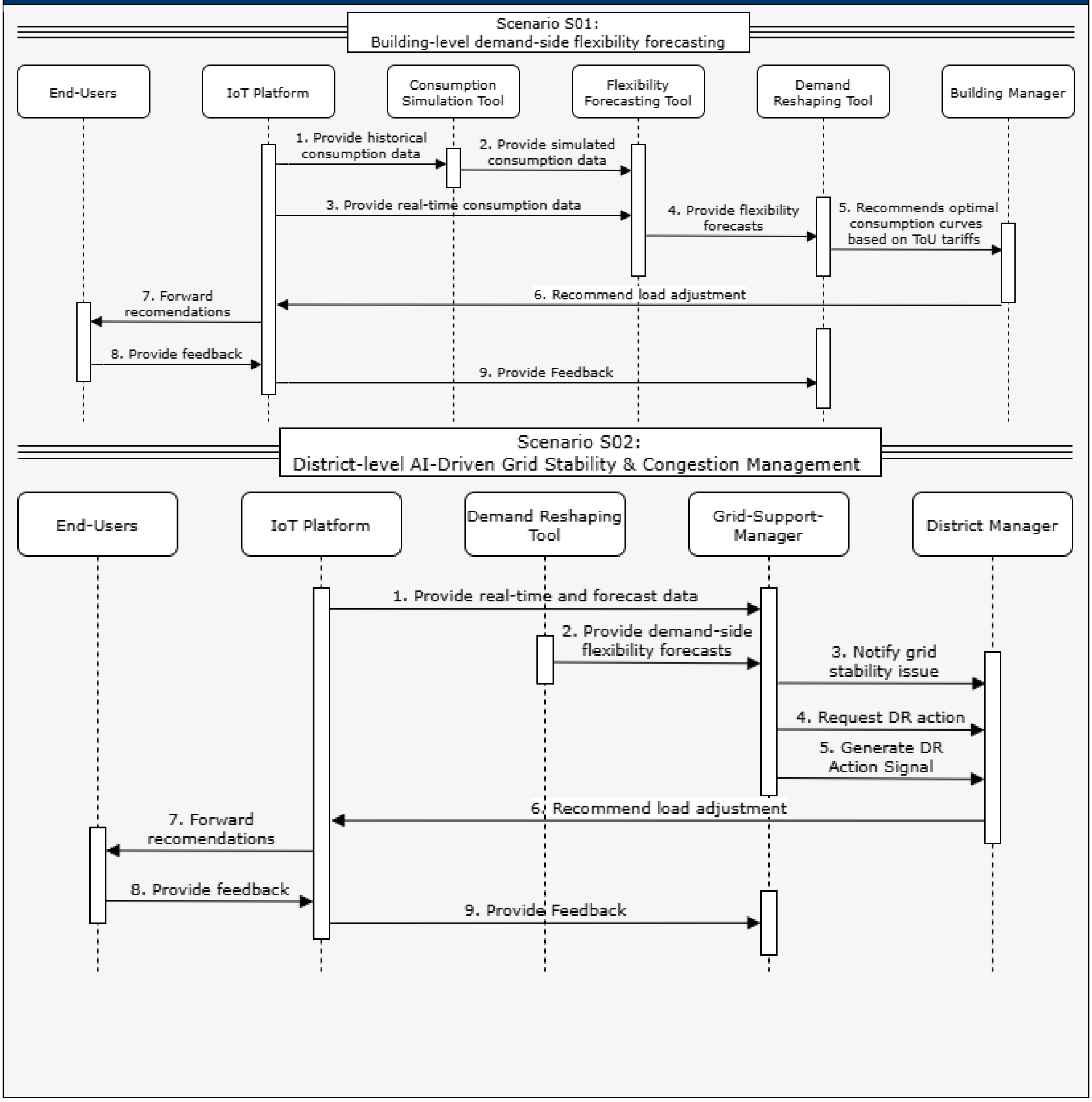
Scope and Objectives of Use Case	
Scope of the use case	This use case aims to establish the most appropriate sequence of actions and collaboration among the available tools, in order to optimize DR participation by leveraging implicit (price-based) and explicit (event-based) demand-side flexibility mechanisms in both building and district level.
Objectives of the use case	• Increase energy efficiency by enhancing the use of renewables and promoting flexibility in demand. • Design and implement smart operational directives to optimize energy flows across integrated resources (generation, demand-side) • Minimize the aggregator's energy costs for a specific demand Demand side flexibility forecasting in a day ahead manner.
Limitations & Assumptions	• Availability of Real-Time and Forecast Data • Demand response strategies require user participation

Narrative of Use Case	
Short Description	This use case provides optimal DR signals, whether through implicit price-based mechanisms (building level) or explicit DR events (district level), without raising the end-users' discomfort above agreed or acceptable levels.
Complete Description	The implicit DR mechanism generates price-based recommendations to influence end-user energy consumption patterns, aligning demand with periods of lower electricity prices or high renewable generation, in building level. The explicit DR mechanism focuses on event-based participation, where users adjust consumption in response to market or grid signals, based on district level optimization.A flexibility forecasting module predicts demand flexibility a day ahead, optimizing DR engagement. The demand reshaping tool dynamically adjusts load in response to market price fluctuations or DR event calls. The system ensures real-time monitoring and feedback collection, refining strategies for future DR participation.

Co-funded by the European Union

Diagrams of the UC

Sequence diagram of the use case



Technical Details of the UC

Actors			
Actor Name	**Actor Type**	**Actor Description**	**Further information specific to this Use Case**
End-users (Flexible Consumers/Buildings)	End-User	Consumers who use the system. Adjust energy consumption based on AI-optimized signals	Includes residential, commercial, or industrial consumers participating in DSM.
IoT platform (and Visual Analytics Engine)	Application	Collects real-time grid data (load, voltage, frequency).	Provides historical and real-time data
Baseline Consumption Simulation Tool	System	Provides simulated consumption data based on historical consumption	
Flexibility Forecasting Tool	System	Real-time power flow analysis: Predicts demand-side flexibility based on historical and real-time data and simulated data.	Provides day-ahead demand flexibility insights
Demand Reshaping Tool	System	Recommends new optimal consumption curves based on ToU tariff on building level	Implements optimal demand reshaping strategies
Grid-Support-Manager	System	AI-driven tool that provides real-time Demand Response (DR) signals and ancillary services (frequency/voltage support) for grid stability.	Generates optimized DR actions for congestion management and grid support.
Building manager	End-User	Responsible for load adjustments at the building level based on received DR signals.	

Co-funded by
the European Union

Actors			
Actor Name	**Actor Type**	**Actor Description**	**Further information specific to this Use Case**
District manager	End-User	Oversees grid operations at the district level and acts as intermediary in DR actions.	

Step-by-step analysis of use case

Overview of scenarios

Scenario Conditions						
No	**Scenario title**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-Condition**
S01	Building-level demand-side flexibility forecasting	Assessment and prediction of demand-side flexibility bounds in a day ahead manner.	Flexibility Forecasting Tool/ Demand Reshaping Tool	Automated Periodic Triggered (DUTh-CERTH)	Availability of historical and real-time energy data access. Availability of weather data	Availability of historical and real-time (simulated?) energy data access. Accurate prediction of demand flexibility bounds for the next day with the use of INTEMA and the Forecasting Tool.
S02	District-level AI-Driven Grid Stability & Congestion Management	The Grid-Support-Manager uses AI-powered solutions to provide grid stability services on district level based on real-time grid conditions.	Grid-Support-Manager	Detection of congestion, or a request from the district manager for support	S01	S02

Steps per scenario

Scenario Name	Building-level demand-side flexibility forecasting							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
1	Receipt of Forecast Data	Demand-Side Flexibility Forecasting	Collect and process day-ahead forecasts to estimate flexibility bounds.	Forecasting and Monitoring	Baseline Consumption Simulation Tool /Forecasting Tool	Demand Reshaping Tool	Demand-Side Flexibility Forecast (INF 5.1)	Accurate real-time and forecast data availability.
2	Forecast or Price Update	Forecasting and Monitoring	Processes day-ahead forecasts or detects significant intra day tariff deviations.	Forecasting and Monitoring	Demand-side Flexibility Forecasting Tool and Electricity Market	Demand Reshaping Tool	Forecast or Tariff Update (INF 5.2)	Real-time or forecast data availability
3	Policy Evaluation	Policy Simulation	Policies are simulated to determine the best trajectory for load adjustments based on updated inputs.	Policy Simulation	Demand Reshaping Tool	Building Manager	Recommended Policies (INF 5.3)	Policy evaluation logic implemented.
4	Policy Recommendation	Load Adjustment reccomendation	The tool sends recommendations to the building manager to adjust loads dynamically.	Load Adjustment reccomendation	Demand Reshaping Tool	Building Manager	Load Adjustment Instructions (INF 5.4)	St3
5	Feedback Collection	Impact Monitoring	The system collects data on policy impact to refine future strategies.	Feedback Collection	IoT platform	Demand Reshaping Tool	Performance Feedback (INF 5.5)	Monitoring and feedback infrastructure.

Co-funded by the European Union

Scenario Name	District-level AI-Driven Grid Stability & Congestion Management							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
1	Data collection	AI-Based Data Monitoring & Analysis	System collects real-time loads and building level flexibility forecasts.	Monitoring & AI Prediction	IoT platform/ Demand reshaping tool	Grid-Support-Manager	Real-time Data (INF 5.6)	Real-time data availability
2	Grid stability issue detected	AI-Based Stability Assessment	AI algorithms assess potential grid instability (congestion)and predict risks.	AI Grid Analysis	Grid-Support-Manager	District manager	Stability Alert (INF 5.7)	AI analytics enabled
3	District manager request or automated trigger	Ancillary Services & DR Action Signal Creation	Based on AI analysis or a direct district manager request, the tool generates custom DR action signals targeting end-users.	DR Management & Ancillary Services	Grid-Support-Manager	District manager	DR Action Signal (INF 5.8)	St2
4	Recommendation of DR action	Load Adjustment & Stability Support reccomendation	The district manager forwards the DR signal, recommending adjustment of consumption, storage, or local generation.	Load Control & Ancillary Services	IoT Platform	End-users	Load Adjustment Reccomendation (INF 5.9)	Active user participation in DR
5	Response evaluation & AI feedback loop	Impact Assessment & AI Optimization	The system collects response data on DR execution, evaluates effectiveness, and uses AI to refine future strategies.	AI Feedback & Optimization	IoT platform	Grid-Support-Manager	Performance Feedback (INF 5.10)	AI-based learning & optimization enabled

Co-funded by
the European Union

3.4. USE CASES OF HUNGARIAN PILOT (HU)

3.4.1. UC – HU 1: Setting up and testing the system to be deployed

Description of the Use Case

Use case Identification		
ID	**Title**	**Domain**
HU1	Setting up and testing the system to be deployed	Smart Buildings, Energy Management, Building Automation

Version Management			
Version No	**Date**	**Name of authors**	**Changes**
01	15.04.2025	Peter Grabner (Profigram), György László (Fair C), Károly Matolcsy (ÉMI)	-
02	04.05.2025	Peter Grabner (Profigram), György László (Fair C), Károly Matolcsy (ÉMI)	Corrections to clarify the use case. Revision and simplification of roles. Improvement of process transparency.

Classification Information	
Pilot Involved	Hungarian Pilot led by Profigram, FAIR C, ÉMI, HORBER
Relation to Other Use Cases	- UC – HU 2: Control system design and construction - UC – HU 4: Integration of Electric Vehicle Charger into the MPC Framework
Related Innovative SEEDS solutions	Microgrid controller for PV production, storage and consumption of the VRV, for optimal operation and maximizing RES
Assets of the UC	VRV system, PV, Storage, EV charger

Co-funded by
the European Union

Scope and Objectives of Use Case	
Scope of the use case	The objective of this use case is to design the system outlined in the Hungarian project section, construct it using commercially available components, and conduct thorough testing. The testing phase will focus on evaluating the performance of the integrated data links, assessing both the physical reliability of the connections and the quality of the transmitted data.
Objectives of the use case	1. **System Design and Implementation**: To design and assemble the target system using commercially available hardware and software components in accordance with the specifications defined in the Hungarian project section. 2. **Integration of Data Links**: To integrate data communication links within the system architecture, ensuring compatibility between components and reliable operation. 3. **Verification of Physical Connectivity**: To test and verify the physical integrity and stability of the data connections under realistic operating conditions. 4. **Data Quality Assessment**: To evaluate the accuracy, consistency, and reliability of the data transmitted through the system's communication links. 5. **Functional Validation**: To confirm that the complete system functions as intended and meets the performance requirements outlined in the project specifications. 6. **Identification of Potential Issues**: To detect and document any operational issues, data loss, or degradation in communication quality during testing. 7. **Documentation and Reporting**: To provide clear documentation of the system setup, test procedures, and results for use in future development phases or replication.
Limitations & Assumptions	<u>Limitations</u>: 1. **Commercial Component Constraints**: The system is limited to the capabilities and specifications of commercially available tools, which may restrict customization and performance optimization. 2. **Testing Environment**: Tests will be conducted under controlled or semi-controlled conditions, which may not fully reflect the variability of real-world operational environments. 3. **Scalability Not Addressed**: The use case focuses on a prototype or demonstration-scale system.

Co-funded by
the European Union

	4. **Limited Duration of Testing**: The testing period may not be long enough to uncover long-term reliability issues or rare intermittent faults in the data links. 5. **Dependency on Manufacturer Specifications**: System performance and integration depend on the accuracy and completeness of vendor-provided documentation and data sheets. 6. **Interoperability Constraints**: There may be limitations in interoperability between components from different vendors due to protocol mismatches or proprietary standards. Assumptions: 1. **Component Availability**: All required hardware and software components are readily available on the commercial market and can be procured within project timelines. 2. **Standard Protocol Support**: It is assumed that all selected components support standard communication protocols compatible with the intended data links. 3. **Stable Power and Network Infrastructure**: The system will be tested in an environment with a stable power supply and network connectivity. 4. **No External Interference**: It is assumed that there will be minimal electromagnetic or physical interference affecting data transmission during testing. 5. **Baseline Configuration Accuracy**: The initial configuration and calibration of system components are assumed to be correct and consistent with manufacturer guidelines.

Narrative of Use Case	
Short Description	This use case focuses on designing and building a prototype system using commercially available components, as defined in the Hungarian pilot. It aims to test the functionality and reliability of integrated data communication links, evaluating both their physical performance and the quality of the transmitted data.
Complete Description	As part of the Hungarian project initiative focused on developing scalable, data-driven solutions, **this use case addresses the practical realization of a digital communication system using off-the-shelf components**. The aim is to bridge the gap between conceptual design and real-world applications by creating a prototype that demonstrates the viability, reliability, and performance of data links in an integrated system. Multiple actors are involved in this effort:

	1. Engineers and Developers aim to design and test communication interfaces and identify challenges before deployment. 2. Project Stakeholders and Funders expect a demonstrable proof-of-concept system that provides insights for future upscaling. 3. End Users (e.g., energy managers or infrastructure operators, the inhabitants of the house) are ultimately interested in systems that ensure data reliability and interoperability with minimal custom development. The use case is designed to deliver these expectations by providing a replicable, test-based methodology for system validation. This use case encompasses the design, assembly, and evaluation of a prototype communication system. The system is to be built entirely from commercially available hardware and software tools. A key focus of the use case is the testing of integrated data links, both in terms of physical connectivity and data quality. The outcomes will inform broader project goals, such as system standardization, integration strategies, and readiness for real-world deployment in smart infrastructure or energy systems. *Methodology and Step-by-Step Implementation*: **1. Requirements Analysis** Functional Requirements (What functions must the system perform?), Performance Requirements (What levels of accuracy, speed, and reliability are needed?), Input/Output (I/O) Listing (What sensors will provide input signals? What actuators need to be controlled? Are they analog or digital signals?), Safety Requirements (What safety functions are necessary? Which standards must be met?), Operator Interface (HMI/SCADA) Needs (How will the operating personnel monitor and control the system? What data needs to be displayed and logged?), Environmental Conditions (Where will the system operate (temperature, humidity, dust, vibration, hazardous areas)? When: At HU pilot initiation Why: To ensure technical alignment with the Hungarian project Who: Modeling expert, control engineer and project managers Expectation: A clear list of required functionalities, interfaces, and performance indicators Output: Specification document including required protocols, data rates, and environmental conditions **2. System Design** a) Architecture Selection: Choosing the most suitable type of control system.), b) Hardware Design:

Co-funded by the European Union

	- Select specific controllers (PLC CPU) and I/O modules based on the specification, - Finalize the types and parameters of sensors and actuators, - Design the network topology and protocols (e.g., Ethernet/IP, Modbus) for communication between devices, - Design the control panel(s) (layout, sizing, cooling), - Design the power distribution (power supplies, circuit breakers), - Design the safety circuits in detail. c) Software Design: - Design the structure of the control logic (e.g., steps of sequential control, state machines, main control loops), - Preliminarily define control algorithms (e.g., initial PID parameters), - Create the design/layout for HMI/SCADA screens. - Develop the data acquisition and logging strategy. - Design the alarm strategy, - Define programming standards and naming conventions. d) Component Selection and Procurement: Based on the designs, select and order the specific hardware components (PLC, modules, sensors, actuators, cables, terminals, switches, power supplies, enclosures, etc.) from suppliers. When: After finalizing system requirements Why: To select the most compatible and cost-effective commercial tools, design the integration of components Who: Engineers and procurement officers Expectation: Availability, technical documentation, support, and protocol compatibility Output: Bill of Materials (BoM) with part numbers, data sheets and detailed technical documentation **3. System Assembly** When: Upon arrival of components Why: To physically construct the system Who: Engineers and system integrators Expectation: Proper cabling, power supply management, physical mounting Output: Fully wired and powered prototype with preliminary communication setup **4. Configuration and Integration** When: Once hardware is set up Why: To configure IP addresses, data rates, protocol stacks, and mappings

Co-funded by the European Union

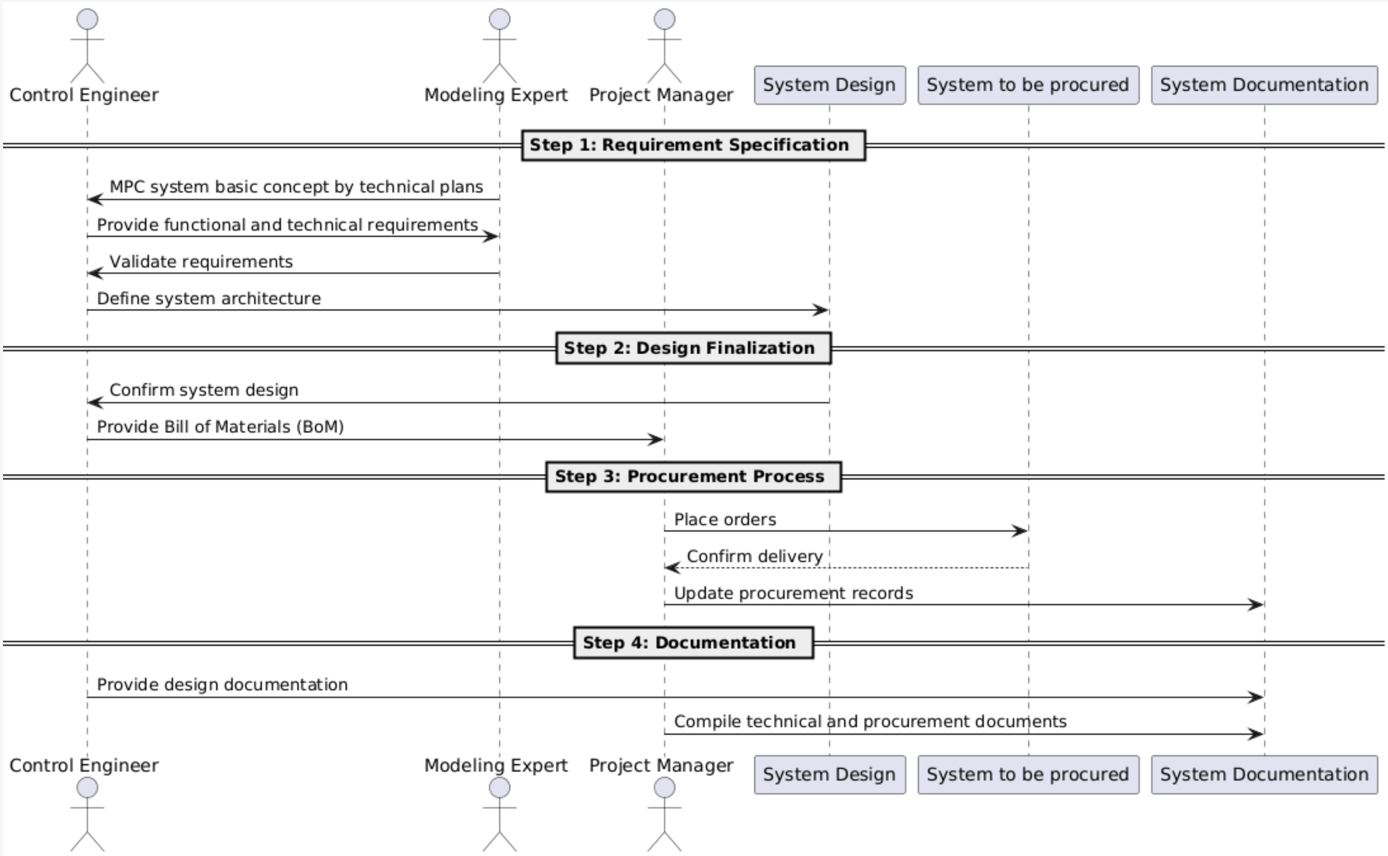
	Who: System software engineers and network specialists Expectation: Establishment of reliable communication between modules Tools: Vendor configuration tools, protocol testers Output: Fully integrated system with functional data links 5. **Testing Phase** When: After configuration Why: To verify system performance and identify issues Who: QA/test engineers Expectations and Tools: • Physical Tests: Cable strain, connection durability • Protocol Tests: Latency, handshake success rate, failover handling • Data Tests: Timestamp accuracy, packet loss, data corruption checks Output: Test reports, error logs, improvement suggestions 6. **Data Quality Assessment** When: During and after testing Why: To ensure data is trustworthy for real-world decision making Who: Data analysts Expectations: No duplicates, synchronization issues, or missing values Output: Data integrity report 7. **Issue Mitigation and Refinement** When: Based on test results Why: To improve reliability and address critical faults Who: Development team Expectation: Final system meets all functional requirements Output: Refined system with improved performance 8. **Final Documentation** When: After testing is complete Why: To ensure reproducibility and transparency Who: All technical teams involved Output: User manual, configuration guide, test results, recommendations This use case delivers a functional, tested, and documented system built from readily available tools, representing a critical step toward scalable and interoperable smart solutions. It not only provides insight into the technical feasibility of commercial integration but also serves as a foundation for future pilot projects, product development, or deployment in energy, infrastructure, or industrial domains.

General Remarks
Primary Actor roles do not necessarily mean a separate team member. This is currently being clarified.

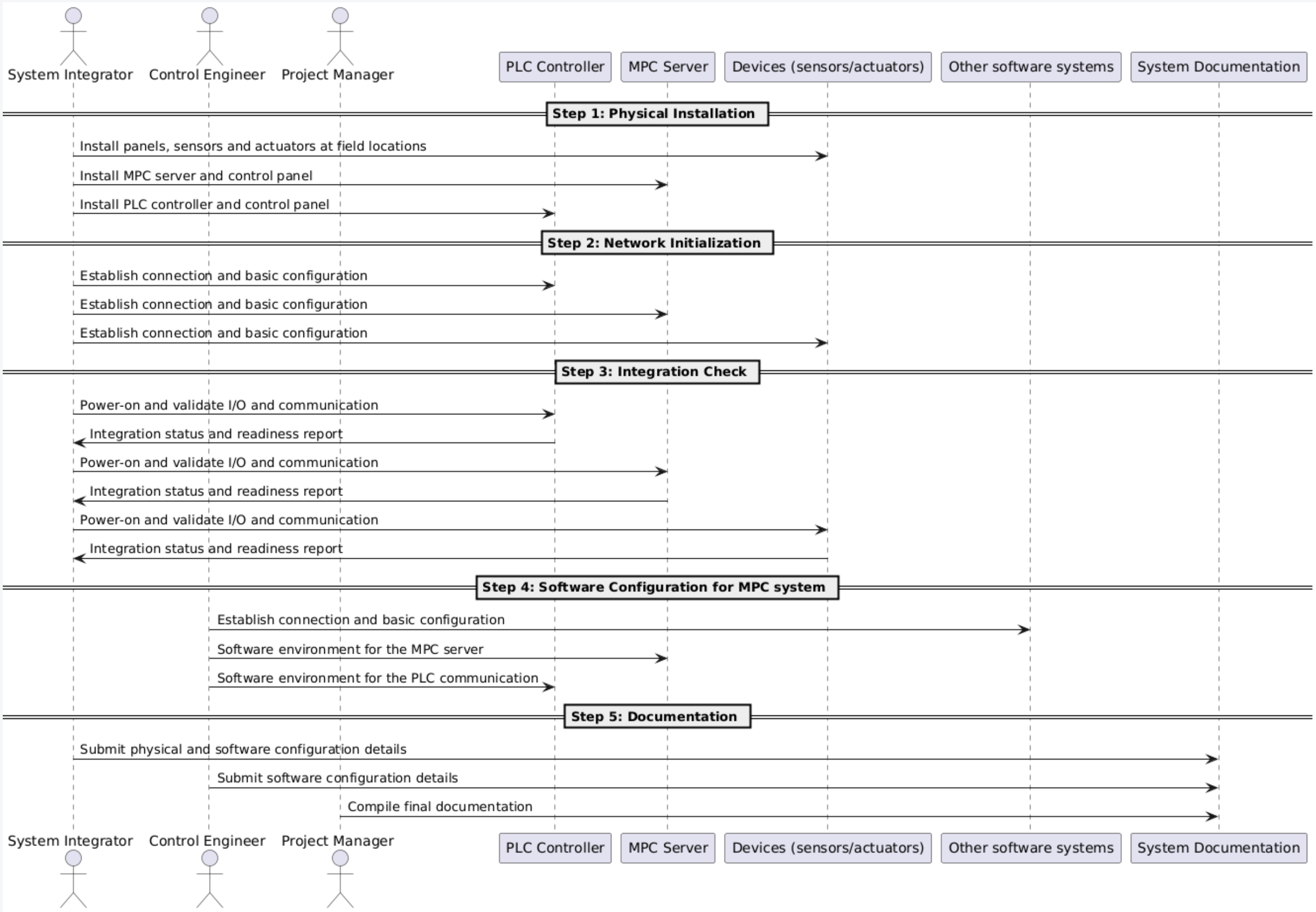
Diagrams of the UC

Sequence diagram of the use case

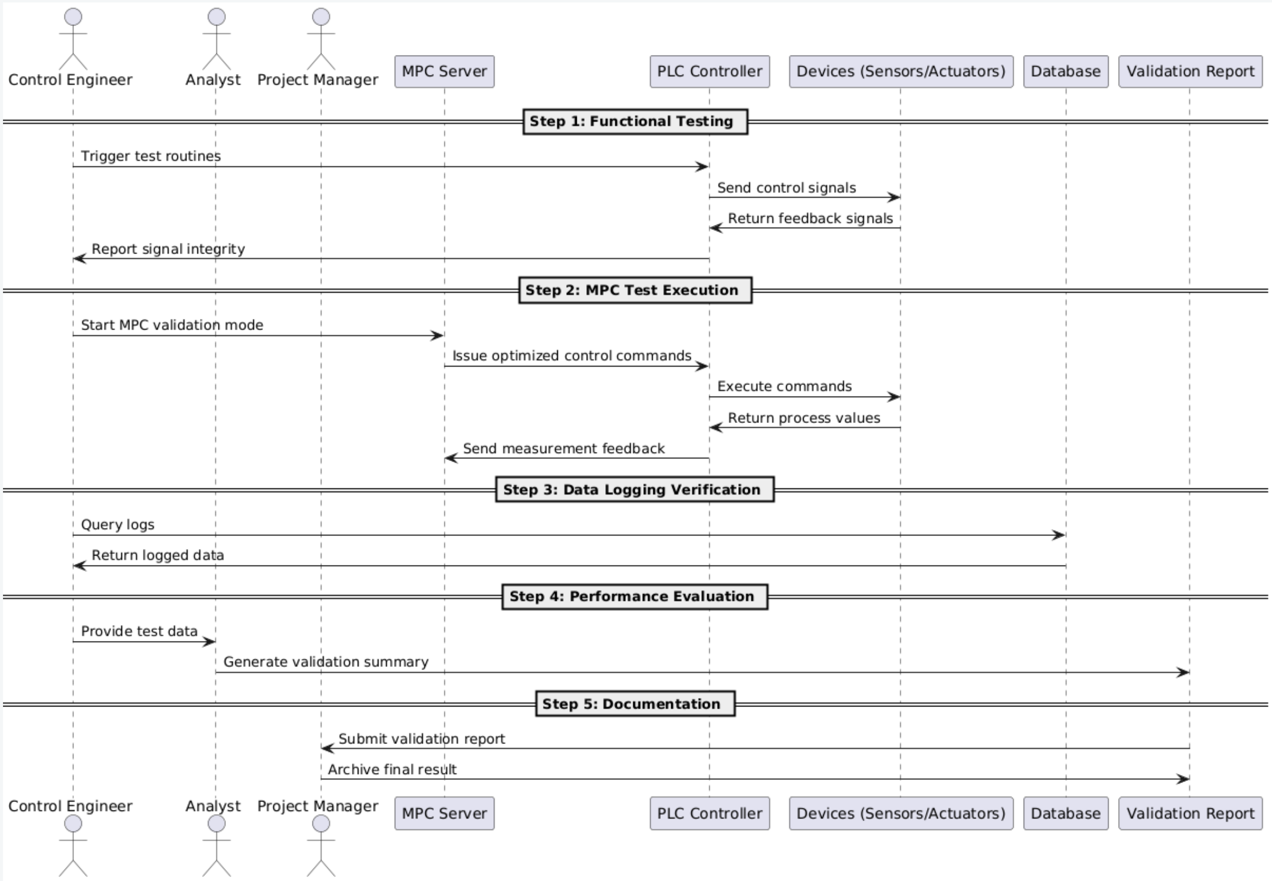
System Planning and Procurement :



System Assembly and Integration


System Integrator
Control Engineer
Project Manager
PLC Controller
MPC Server
Devices (sensors/actuators)
Other software systems
System Documentation
Step 1: Physical Installation
Install panels, sensors and actuators at field locations
Install MPC server and control panel
Install PLC controller and control panel
Step 2: Network Initialization
Establish connection and basic configuration
Establish connection and basic configuration
Establish connection and basic configuration
Step 3: Integration Check
Power-on and validate I/O and communication
Integration status and readiness report
Power-on and validate I/O and communication
Integration status and readiness report
Power-on and validate I/O and communication
Integration status and readiness report
Step 4: Software Configuration for MPC system
Establish connection and basic configuration
Software environment for the MPC server
Software environment for the PLC communication
Step 5: Documentation
Submit physical and software configuration details
Submit software configuration details
Compile final documentation
System Integrator
Control Engineer
Project Manager
PLC Controller
MPC Server
Devices (sensors/actuators)
Other software systems
System Documentation

Validation



Technical Details of the UC

Actor Name	Actor Type	Actor Description	Further Information Specific to this Use Case
Modeling Expert	Human	Basic MPC system design	He is responsible for developing the basic concept of the MPC system and providing data and information for hardware design.
Control Engineer	Human	Responsible for translating project requirements into system architecture and define compatible hardware/software components	Initiates the design process based on specifications from the Hungarian pilot site.
System Integrator	Human	Assemble and integrate physical	Connect components and ensure data links are

		and software components of the system.	physically and logically functioning.
Data Analyst	Human	Verifies system functionality, physical link stability, and operational performance.	Runs tests to validate physical links, communication, and system reliability.
Project Manager	Human	Oversee the entire use case process and ensure objectives and documentation are met.	Compiles reports and documentation based on testing results and coordinates between technical roles.
System to be procured	System	Equipment necessary for system construction and testing	It consists of various commercially sourced components and serves as the test platform.
PLC Controller	System	Programmable Logic Controller	A PLC (Programmable Logic Controller) is a rugged industrial computer that automates machines and processes. It continuously reads inputs (from sensors), executes a user-written program (control logic), and controls outputs based on that logic and the parameters of the MPC server.
MPC server	System	A server running the complex MPC algorithm	An MPC server would be a computer or server running the complex MPC algorithm. It receives real-time data from the plant (PLC), runs the optimization calculations, and sends the calculated optimal control actions (e.g., setpoints for lower-level controllers) back to the control system.
Devices	System	All equipment necessary for the construction of the system.	Sensors, actuators, PLC, Industrial PC

System document	Document	Summary document for the scenario	This document summarizes the conceptual, implementation, and testing plans for the scenario, as well as the testing and tuning results.

Step-by-step analysis of use case

Overview of scenarios

Scenario Conditions						
No	**Scenario title**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-Condition**
1	System Planning and Procurement	The project team begins designing the system according to the project specification. and based on commercial components.	Control Engineer	Project scope is approved	The basic requirements are clear. The architectural, mechanical, and electrical designs have been completed and are available.	System design is completed and documented. The necessary purchases have been made. Reports and plans are created
2	System Assembly and Integration	The system is physically built and wired based on the design plan.	System Integrator	Components are received.	All components are available and ready for assembly.	Communication between system parts is established. Hardware interfaces are physically connected. The data connections are working, and the sensors are accessible. Reports are created
3	Validation	The system is tested for expected behaviors and operational scenarios. The team verifies the physical stability and robustness of the data links and assesses the accuracy and reliability of transmitted data.	Control Engineer	All components are configured	Complete system is online and stable.	System passes (or fails) all functional tests. Physical communication links are validated. Data quality is assessed and confirmed (or issues are logged) Reports are created

Co-funded by the European Union

Scenario Name:	System Planning and Procurement							
Step No.	**Event**	**Name of Process/Activity**	**Description of Process/Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information Exchanged**	**Requirements (R-ID)**
1.1	Concept Development	MPC system basic concept by technical plans	ME shares the conceptual foundation of the MPC system based on technical plans.	System Design Service	Modeling Expert (ME)	Control Engineer (CE)	Conceptual MPC framework	R-ID-01
1.2	Requirements Exchange	Provide functional and technical requirements	CE specifies the functional and technical requirements for system development.	Specification Service	Control Engineer (CE)	Modeling Expert (ME)	Functional requirements document	R-ID-02
1.3	Requirement Validation	Validate requirements	ME reviews and validates the requirements for correctness and feasibility.	Review Service	Modeling Expert (ME)	Control Engineer (CE)	Validated requirements	R-ID-02
1.4	System Architecture Definition	Define system architecture	CE defines the overall architecture based on validated requirements.	System Design Service	Control Engineer (CE)	System Design (SD)	System architecture diagram	R-ID-02
2.1	Design Confirmation	Confirm system design	SD confirms the finalized system design to the CE.	Design Confirmation	System Design (SD)	Control Engineer (CE)	Confirmed system design	R-ID-02
2.2	BoM Preparation	Provide Bill of Materials (BoM)	CE prepares and delivers the list of required components to the PM.	Specification Service	Control Engineer (CE)	Project Manager (PM)	Bill of Materials (BoM)	R-ID-03
3.1	Ordering Components	Place orders	PM places orders for components with selected suppliers.	Procurement Service	Project Manager (PM)	Procurement System (PS)	Purchase orders	R-ID-03
3.2	Order Confirmation	Confirm delivery	PS confirms receipt and processing of orders to PM.	Procurement Confirmation	Procurement System (PS)	Project Manager (PM)	Delivery confirmations	R-ID-03

3.3	Procurement Record Update	Update procurement records	PM updates internal records with procurement and delivery status.	Procurement Documentation	Project Manager (PM)	System Documentation (DOC)	Procurement logs	R-ID-03
4.1	Design Documentation	Provide design documentation	CE submits design documents for official project records.	Documentation Service	Control Engineer (CE)	System Documentation (DOC)	Design documents	R-ID-10
4.2	Documentation Compilation	Compile technical and procurement documents	PM compiles all relevant documentation into a project report.	Documentation Service	Project Manager (PM)	System Documentation (DOC)	Compiled project documentation	R-ID-01 R-ID-02 R-ID-03

Scenario Name:	**System Assembly and Integration**							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information Exchanged**	**Requirements (R-ID)**
1.1	Field Installation	Install panels, sensors and actuators	System Integrator installs panels, sensors, and actuators at field locations.	Installation Service	System Integrator (SI)	Devices (DEV)	Installed field hardware	R-ID-01
1.2	Server Installation	Install MPC server and control panel	System Integrator installs the MPC server and its related infrastructure.	Installation Service	System Integrator (SI)	MPC Server	Mounted MPC hardware	R-ID-01
1.3	PLC Installation	Install PLC controller and control panel	System Integrator installs the PLC controller and connects it to the system.	Installation Service	System Integrator (SI)	PLC Controller	Installed PLC hardware	R-ID-01
2.1	PLC Connection	Establish connection and basic configuration	Basic network setup and handshake procedures are	Network Configuration	System Integrator (SI)	PLC Controller	Basic config parameters	R-ID-01

Co-funded by the European Union

			established with the PLC.					
2.2	MPC Connection	Establish connection and basic configuration	Basic network setup and handshake procedures are established with the MPC.	Network Configuration	System Integrator (SI)	MPC Server	Basic config parameters	R-ID-01
2.3	Device Connection	Establish connection and basic configuration	Devices are connected to the system and undergo basic communication checks.	Network Configuration	System Integrator (SI)	Devices (DEV)	Connectivity report	R-ID-01
3.1	PLC Integration Test	Power-on and validate I/O and communication	Power is applied to the PLC and communication and I/O signals are verified.	Integration Test	System Integrator (SI)	PLC Controller	Integration test results	R-ID-01
3.2	MPC Integration Test	Power-on and validate I/O and communication	Power is applied to the MPC and interfaces are verified.	Integration Test	System Integrator (SI)	MPC Server	Integration test results	R-ID-01
3.3	Device Integration Test	Power-on and validate I/O and communication	Devices are powered up and communication paths and functionality are checked.	Integration Test	System Integrator (SI)	Devices (DEV)	Integration test results	R-ID-01
4.1	DB Configuration	Establish connection and basic configuration	Control Engineer connects software components to the database/logging environment.	Software Setup	Control Engineer (CE)	Other software systems (DB)	Software connection settings	R-ID-1
4.2	MPC Software	Software environment for the	CE installs and configures the software	Software Setup	Control Engineer (CE)	MPC Server	Software installation and config files	R-ID-1

Co-funded by the European Union

	Configuration	MPC server	environment needed for MPC operation.					
4.3	PLC Communication Setup	Software environment for the PLC communication	CE configures communication layers and logic for MPC-to-PLC interaction.	Software Setup	Control Engineer (CE)	PLC Controller	Comm configuration	R-ID-1
5.1	Submit System Configuration	Submit physical and software configuration details	System Integrator provides detailed setup and wiring documentation.	Documentation	System Integrator (SI)	System Documentation	Hardware configuration record	R-ID-1
5.2	Submit Software Documentation	Submit software configuration details	Control Engineer provides software installation and configuration documents.	Documentation	Control Engineer (CE)	System Documentation	Software config documentation	R-ID-1
5.3	Compile Final Documentation	Compile final documentation	Project Manager gathers all documents into the official project archive.	Documentation	Project Manager (PM)	System Documentation	Complete documentation package	R-ID-1

Scenario Name:	**Validation**							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information Exchanged**	**Requirements (R-ID)**
1.1	Trigger Functional Test	Trigger test routines	The Control Engineer triggers predefined test routines on the PLC to evaluate system response.	Functional Testing	Control Engineer (CE)	PLC Controller	Test command	R-ID-01

1.2	Execute Device Control	Send control signals	PLC sends control signals to the devices as part of the test sequence.	Device Control	PLC Controller	Devices (Sensors/Actuators)	Actuation commands	R-ID-01
1.3	Receive Device Feedback	Return feedback signals	Devices send feedback signals to confirm their operation and test status.	Signal Response	Devices (Sensors/Actuators)	PLC Controller	Sensor readings	R-ID-01
1.4	Evaluate I/O Integrity	Report signal integrity	PLC evaluates the correctness and timing of feedback and reports back to CE.	Signal Evaluation	PLC Controller	Control Engineer (CE)	Integrity report	R-ID-01
2.1	Start MPC Validation	Start MPC validation mode	Control Engineer activates the validation mode on the MPC server.	Validation Mode Activation	Control Engineer (CE)	MPC Server	Mode start signal	R-ID-01
2.2	Control Loop Execution	Issue optimized control commands	MPC sends optimized control signals to PLC based on internal algorithms.	MPC Execution	MPC Server	PLC Controller	Control setpoints	R-ID-01
2.3	Perform Device Actions	Execute commands	PLC forwards commands to devices, which perform the requested actions.	Execution Control	PLC Controller	Devices (Sensors/Actuators)	Action execution	R-ID-01
2.4	Return Measurements	Return process values	Devices provide process measurements back to PLC.	Feedback Data	Devices (Sensors/Actuators)	PLC Controller	Measurement values	R-ID-01
2.5	Feedback to MPC	Send measurement feedback	PLC sends the received feedback data to MPC for evaluation.	Feedback Loop	PLC Controller	MPC Server	Feedback report	R-ID-01
3.1	Verify Logging	Query logs	Control Engineer queries the database for recorded test and operation data.	Data Logging Verification	Control Engineer (CE)	Database (DB)	Query request	R-ID-1
3.2	Return Logs	Return logged data	Database returns logs for verification.	Data Retrieval	Database (DB)	Control Engineer (CE)	Logged values	R-ID-1

Co-funded by the European Union

4.1	Transfer Test Data	Provide test data	Control Engineer shares the collected test data with the Analyst.	Test Reporting	Control Engineer (CE)	Analyst (AN)	Test dataset	R-ID-1
4.2	Generate Report	Generate validation summary	Analyst creates a validation summary report from test results.	Report Generation	Analyst (AN)	Validation Report	Validation summary	R-ID-1
5.1	Submit Report	Submit validation report	The report is delivered to the Project Manager.	Submission	Validation Report	Project Manager (PM)	Validation report	R-ID-2
5.2	Archive Results	Archive final result	Project Manager archives the final validation report for project documentation.	Archiving	Project Manager (PM)	Validation Report	Archived report	R-ID-2

Co-funded by
the European Union

3.4.2. UC – HU 2: Control system design and construction

Description of the Use Case

Use case Identification		
ID	**Title**	**Domain**
HU2	Control system design and construction	Smart Buildings, Energy Management, Building Automation

Version Management			
Version No	**Date**	**Name of authors**	**Changes**
01	15.04.2025		
02	04.05.2025	Péter Grabner (Profigram), György László (Fair C), Károly Matolcsy (ÉMI)	Corrections to clarify the use case. Revision and simplification of roles. Improvement of process transparency.

Classification Information	
Pilot Involved	Hungarian Pilot led by Profigram, FAIR C, ÉMI, HORBER
Relation to Other Use Cases	- UC – HU 1: Setting up and testing the system to be deployed - UC – HU 4: Integration of Electric Vehicle Charger into the MPC Framework
Related Innovative SEEDS solutions	- VRV system for central heating replacing individual room gas burner in residential buildings - BEMS and Microgrid for integration and optimization of the integrated system in apartment buildings
Assets of the UC	VRV, PV, Storage, EV charger, BEMS, Microgrid

Co-funded by
the European Union

Scope and Objectives of Use Case	
Scope of the use case	The scope of this use case is to design, implement, and test a Model Predictive Control (MPC) system on the prototype developed in the first use case. The MPC will be integrated into the existing system architecture, which is composed of commercially available components and validated communication links. The primary focus is on using MPC to achieve optimal and predictive control of the system by leveraging real-time data and a process model to anticipate system behavior and adjust control actions accordingly. This use case encompasses all steps from model development and control logic design to software integration, simulation, and real-time deployment. The MPC will be tested under realistic operational conditions to evaluate its ability to manage system dynamics, constraints, and disturbances. The implementation should demonstrate enhanced performance, stability, and energy efficiency compared to traditional control approaches.
Objectives of the use case	1. **Develop a Dynamic System Model**: Build or identify a mathematical model that accurately represents the behavior of the prototype system using real data collected via validated communication links. 2. **Formulate an MPC Control Strategy**: Define the prediction model, cost function, constraints, and optimization horizon for the MPC controller to ensure optimal and constraint-respecting control actions. 3. **Integrate MPC into the Existing System Architecture**: Embed the MPC logic into the prototype system, ensuring compatibility with the existing hardware and communication interfaces established in the first use case. 4. **Simulate and Validate MPC Performance**: Perform closed-loop simulations to test the performance, robustness, and stability of the MPC controller under different operating conditions and disturbances. 5. **Deploy the MPC in Real-Time Operation**: Implement and test the MPC in the real system environment, using actual sensor data and control actuation, and monitor system response. 6. **Evaluate Control Quality and Efficiency**: Analyze system performance metrics such as response time, energy consumption, stability, and tracking accuracy to validate the added value of predictive control. 7. **Ensure Safety and Robustness Under Constraints**: Verify that the MPC can handle system constraints (e.g., input/output limits) and maintain safe operation even in the presence of uncertainties. 8. **Document Control Design and Tuning Parameters**: Provide comprehensive documentation of the MPC setup, including model

Co-funded by the European Union

	parameters, control weights, constraints, and tuning guidelines for reproducibility.
Limitations & Assumptions	<u>Limitations</u>: 1. **Model Accuracy**: The effectiveness of the MPC depends heavily on the accuracy of the system model. Inaccurate or oversimplified models may degrade control performance. 2. **Computational Complexity**: Real-time optimization required by MPC can be computationally intensive, especially for non-linear or constrained systems, limiting the controller's responsiveness on low-power hardware. 3. **Finite Prediction Horizon**: The use of a limited prediction horizon may not capture all long-term system effects, potentially affecting stability and performance in slow-dynamic systems. 4. **Limited Testing Scope**: Testing is conducted on a prototype platform under controlled conditions, which may not represent all real-world disturbances or operational environments. 5. **Constraint Handling**: While input constraints are treated as hard limits, output constraints may only be enforced through soft penalties, leading to possible violations during unexpected disturbances. 6. **Dependency on Communication Stability**: Real-time control performance assumes stable and timely data exchange, which relies on the quality of the communication links validated in the first use case. <u>Assumptions</u>: 1. **Validated System Model**: A reliable model of the system (linear or non-linear) is available or can be developed using historical or real-time data. 2. **Stable Operating Conditions**: The system is assumed to operate in a stable environment without unexpected disruptions or failure of critical components. 3. **Sufficient Computational Resources**: The processing platform (e.g., embedded controller, industrial PC) is assumed to have enough computational capacity to run the MPC algorithm in real time. 4. **Data Availability and Quality**: High-quality, real-time measurements of inputs and outputs are available via the data links from the first use case. 5. **Known Constraints**: All relevant system constraints (e.g., actuator limits, safety margins) are assumed to be well-defined and constant during operation. 6. **Controller Initialization is Feasible**: It is assumed that the MPC controller can be initialized with a feasible state estimate and that the optimization problem is solvable at each time step.

Narrative of Use Case	
Short Description	This use case focuses on the development and integration of a Model Predictive Control (MPC) system into a prototype platform previously designed and tested with commercial components. The MPC aims to enhance system performance by using real-time data and a predictive model to optimize control actions under constraints. The implementation includes model formulation, real-time optimization, system integration, and performance evaluation in a realistic testing environment.
Complete Description	The scope of this use case is to design, implement, and test a Model Predictive Control system as an intelligent layer on top of the prototype platform developed in the first use case. The prototype system, which features validated data communication links and hardware integration, will serve as the physical environment for deploying and evaluating the MPC. This use case involves: • Developing or identifying a system model based on real data, • Designing an MPC controller with constraints and optimization logic, • Integrating the MPC into the prototype system architecture, and • Testing the control system in real-time to evaluate its performance in terms of stability, constraint handling, and overall control quality. In the first use case, a prototype system was successfully designed, built, and tested using commercial components. This prototype includes data acquisition capabilities and reliable data links. Building on this foundation, the second use case aims to implement a smart control strategy—Model Predictive Control—that uses real-time optimization to forecast future behavior and adjust control inputs accordingly. MPC offers advantages such as: • Predictive and anticipatory behavior, • Explicit handling of system constraints, • Robustness to disturbances and uncertainty, • Superior tracking performance compared to classical PID control. The implementation of MPC will demonstrate the benefits of advanced control technologies on a functional prototype and lay the groundwork for future deployment in production systems, energy management, or industrial automation. *Methodology and Step-by-Step Implementation* 1. **Requirements Analysis**: Translate operational goals of the prototype into MPC objectives (e.g., minimize energy use, stabilize temperature etc.). When: At HU pilot initiation

Co-funded by the European Union

	Why: To define control objectives, constraints, and performance expectations Who: System designers and control engineers Input: Prototype specifications, process knowledge Output: List of control goals (e.g., setpoint tracking, constraint management, energy efficiency) 2. **Data Acquisition and Preprocessing:** Use the data collected from the prototype (via integrated data links) to develop or refine a mathematical model of the system (state-space) When: After prototype testing is complete (Use Case 1) Why: To gather relevant input-output data for system identification Who: Data engineers, control team Input: Logged sensor data, actuator commands Output: Cleaned and structured datasets for modeling 3. **System Identification and Modeling:** When: Following data preprocessing Why: To derive a predictive model of the system Who: Control engineers, system modelers **a)** ***Zone Thermal Models***: Developing dynamic thermal models for each zone. These models will predict the future temperature of each zone based on various inputs. Consider factors like: • *Heat transfer coefficients*: Walls, windows, roof, floor (R-values, U-values). • *Thermal mass*: Capacity of walls, , air to store heat. • *Infiltration and ventilation*: Air leakage and airflow. • *Internal heat gains*: Occupants, lights, equipment. • *Solar radiation*: Incident solar gains through windows and walls (consider orientation and shading). • *Inter-zone heat transfer*: If applicable, model heat exchange between adjacent zones. Model complexity can range from simple first-order RC (Resistance-Capacitance) networks to more complex multi-state models. The choice depends on the desired accuracy and computational cost. ***b) VRV Heat Pump Model*** Consider factors like: • *Heating and cooling capacity:* Dependent on outdoor temperature, indoor setpoints, and the number of active indoor units.

	• *Energy consumption*: Relate power input to heating/cooling output (Coefficient of Performance - COP, Energy Efficiency Ratio - EER). These are often non-linear. • *Operational constraints*: Minimum/maximum capacity, ramp rates. • *Multi-zone operation*: How the central unit distributes heating/cooling to different zones. This might involve capacity sharing or prioritization logic. • *Partial Load Efficiency:* VRV systems often have better efficiency at partial loads. The MPC should exploit this by modulating the capacity rather than just turning units on and off. • *Minimum Run Times:* Consider minimum on/off times for the VRV compressor to avoid short cycling. • *Capacity Distribution:* The MPC needs to decide how to distribute the available heating/cooling capacity among the different zones based on their demands and priorities. This can be complex due to the interconnected nature of the VRV system. • *Defrost Cycles:* If operating in heating mode at low outdoor temperatures, consider the impact of defrost cycles on the system's output. ***c) PV System Model:*** Model the power generation of the photovoltaic system mainly based on solar irradiance and temperature. Consider factors like: • *Panel characteristics*: Efficiency, area, tilt angle, orientation. • *Solar irradiance data*: Forecasts are crucial for predictive control. • *Inverter efficiency*. ***d) Battery System Model:*** This model will allow the MPC to optimally charge and discharge the battery to achieve objectives like cost reduction, self-consumption maximization, and grid support. Consider factors like: • *State of Charge (SOC) Dynamics* • *Power Constraints* • *SOC Limits* • *Efficiency Considerations* • *Degradation Model* • *Initial Conditions* ***e) Model Parameter Estimation:*** Obtain real-world data (temperature measurements, energy consumption, weather data) to identify and

	validate the parameters of the developed models. Techniques like system identification algorithms (e.g., least squares) can be used. ***f) Defining Objectives:*** What do we want to achieve with the MPC? • *Thermal comfort*: Maintaining zone temperatures within a desired range. This can involve minimizing deviations from setpoints or satisfying comfort indices (e.g., PMV/PPD). • *Energy efficiency*: Minimizing the energy consumption of the heating/cooling system. • *Cost optimization*: Minimizing the operational cost, considering electricity prices and potential feed-in tariffs for PV. • *Load shifting*: Utilizing PV generation effectively and reducing peak electricity demand. • *Prioritizing zones*: Maintaining tighter temperature control in critical zones. ***g) Defining Constraints:*** What limitations must the system operate within? • *Temperature limits:* Minimum and maximum allowed temperatures for each zone. • *Actuator limits:* Maximum heating/cooling capacity of the VRV system, individual indoor unit capacity limits, ramp rate limits. • *Energy constraints:* Limits on total energy consumption or peak demand. • *Operational constraints:* Minimum on/off times for equipment. • *PV power availability:* The heating/cooling cannot exceed the available PV power (if aiming for self-consumption). ***h) Prediction and Forecasting:*** • *Weather Forecasting:* Obtain accurate forecasts of outdoor temperature, solar radiation, wind speed, and humidity over the prediction horizon. • *Occupancy Schedules:* Predict occupancy patterns for each zone, as this influences internal heat gains and comfort requirements. • *Internal Gains:* Estimate future internal heat gains from lights and equipment based on schedules or usage patterns. Output: A validated model suitable for MPC (discrete time, observable, accurate) **4. Formulating the Optimization Problem:** When: Once a usable model is established Why: To design the controller using prediction and control horizons, weights, and constraints

	Who: Control engineers a) **Control Variables (Inputs)**: These are the variables that the MPC can manipulate to control the system. Examples include: • Heating/cooling power supplied to each zone by the VRV system. • Setpoints for individual indoor units (if directly controllable). • Activation/deactivation of auxiliary heating/cooling devices. b) **State Variables**: These are the variables that describe the current state of the system and are predicted by the models (e.g., zone temperatures). c) **Output Variables**: These are the variables that you want to control or monitor (e.g., zone temperatures, energy consumption). d) **Optimization Problem Formulation:** The MPC solves an optimization problem at each time step. To do this, the control variables, state variables and outputs must be used to define all the equations and inequalities that describe the overall system. e) **Cost Function**: Define a mathematical function that quantifies the objectives. This function will be minimized by the MPC. It typically includes terms related to: • Temperature deviations from setpoints (weighted by importance). • Energy consumption (weighted by cost). • Actuator usage (to avoid excessive switching). • Potential penalties for constraint violations. Output: Mathematical formulation of the MPC optimization problem 5. **Controller Simulation and validation** When: Before deployment Why: To test the MPC in a virtual environment and verify performance Who: Control engineers Tools: Python or other simulation frameworks Output: Verified behavior of the MPC in nominal and disturbed conditions 6. **Control Integration**: Integrate the MPC algorithm into the prototype system's architecture. When: After simulation validation Why: To implement the controller in the physical prototype Who: System integrators Steps: Embed MPC algorithm on hardware (e.g. PLC, industrial PC) Interface with sensors/actuators via communication links Output: Working MPC module in the prototype environment 7. **Online Testing & Tuning**: Run closed-loop tests in real-time. Tune weights, horizons, and slack penalties based on observed performance. When: Post-integration

Co-funded by
the European Union

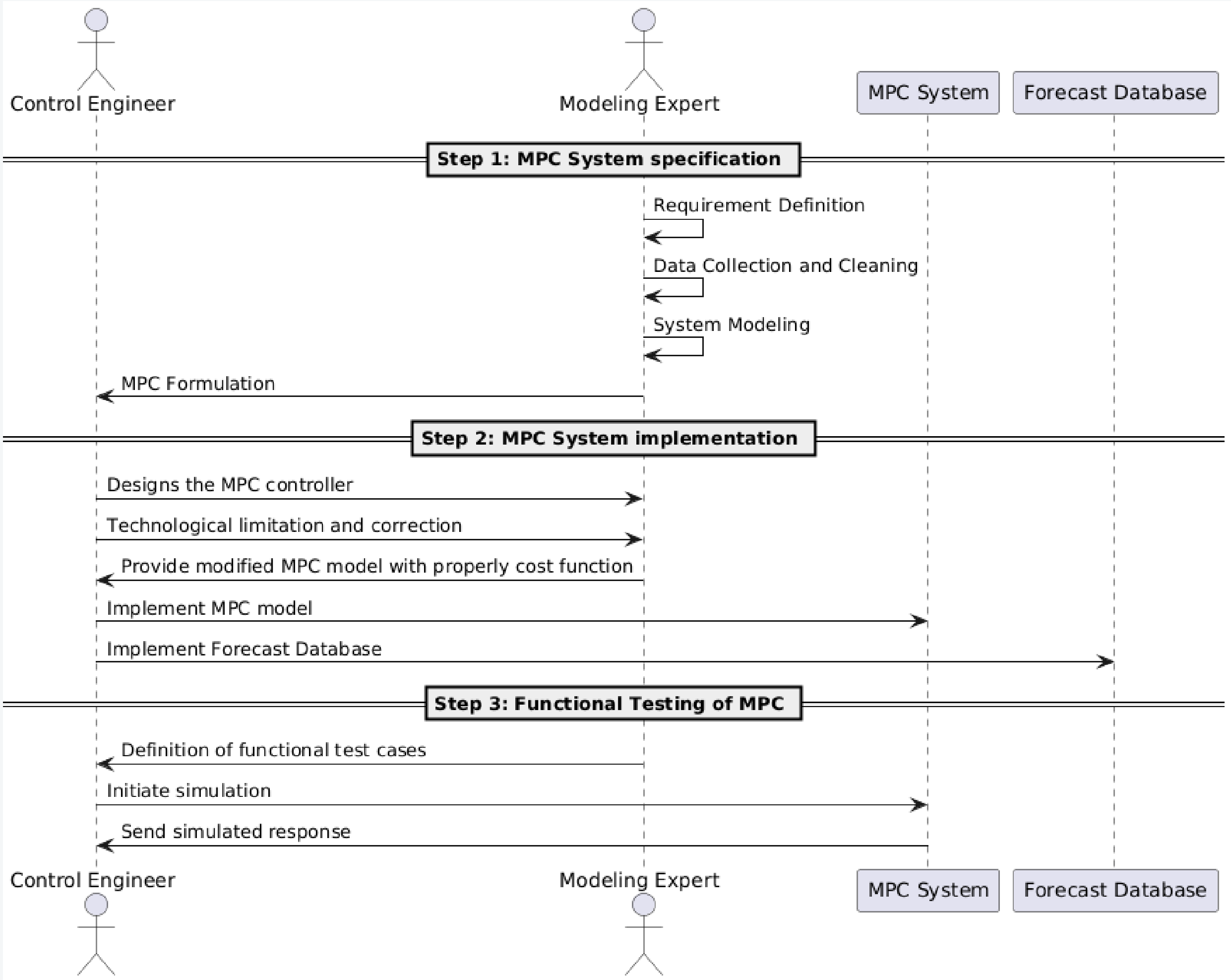
	Why: To test the control system in real conditions and adjust parameters Who: QA engineers, control developers Focus Areas: Feasibility of optimization, Execution time (sample rate compliance), Constraint handling under disturbances a) **Initial Parameter Tuning:** Adjust the weights in the cost function and the constraints to achieve the desired performance. b) **Validation:** We must validate the MPC system through simulations and real-world testing. c) **Adaptive Control:** We consider implementing adaptive control techniques to update the model parameters online based on real-time data, accounting for changes in building characteristics or system performance. Output: Tuned, stable, and responsive MPC system 8. **Performance Evaluation** When: After sustained testing Why: To assess improvements over baseline and validate KPIs Who: Analysts Metrics: Setpoint tracking, energy savings, constraint satisfaction, robustness Output: Performance report 9. **Documentation & Finalization:** Document the MPC design choices, performance metrics, controller settings, and provide tuning guidelines for future users. When: At the end of testing Why: To support reproducibility, tuning, and future development Who: Technical writers, Engineers Deliverables: Controller structure, Tuning parameters, Simulation files, Implementation guidelines Output: Full documentation for operational use or replication

General Remarks
Primary Actor roles do not necessarily mean a separate team member. This is currently being clarified.

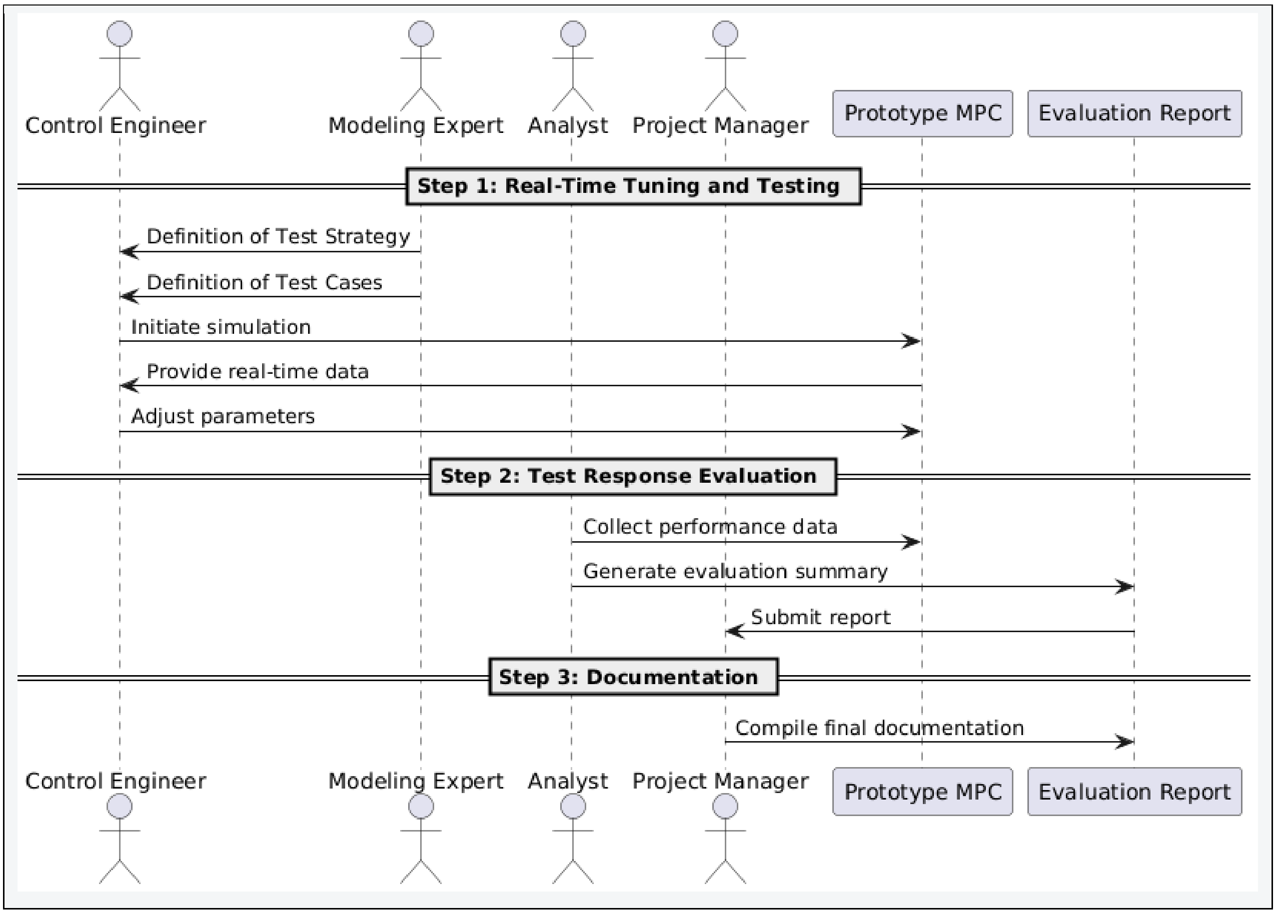
Co-funded by
the European Union

Diagrams of the UC

Sequence diagram of the use case
System design and implementation:



Real-Time System Testing and Performance Evaluation:



Technical Details of the UC

Actor Name	Actor Type	Actor Description	Further Information Specific to this Use Case
Control Engineer	Human	Designs the MPC controller. Develops or adapts the software environment for implementing MPC algorithms. Implements the MPC logic into the physical prototype using available hardware.	Responsible for implementing the MPC system and ensuring that it operates according to the specified logic. During implementation, he/she programs the PLC used during operation and the software modules that implement the MPC operation. May use Python or embedded C for controller deployment on the platform.
Modeling Expert	Human	Designs the MPC controller including model selection	Responsible for developing and validating the core logic of the MPC system. Prepares datasets used in modeling and evaluates control performance metrics.
Data Analyst	Human	Tests and validates the performance of the integrated system.	Runs simulations and real-time tests to verify correct charger control behavior.

Co-funded by the European Union

Project Manager	Human	Oversee the use case timeline, coordination, and documentation.	Ensure all design steps are followed, tests are completed, and deliverables are compiled.
MPC Controller	Software Module	The algorithm that computes optimal control actions based on predictions.	Implemented using a control toolbox or custom code; directly controls system actuators.
Forecast Database	Software Module	This database stores external data used by MPC.	The MPC uses a lot of data during operation. Some of this data comes from measurements taken from the system, while other data comes from external sources. This data is stored in this database.
Evaluation Report	Document	Summary document for the scenario	This document summarizes the conceptual, implementation, and testing plans for the scenario, as well as the testing and tuning results.

Step-by-step analysis of use case

Overview of scenarios

Scenario Conditions						
No	**Scenario Title**	**Scenario Description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	System design and implementation	In this scenario, the external data collection and the design and implementation of the MPC system software are carried out using the installed hardware components. We define the conditions used in the model and the cost function. We build a working MPC system.		Start of Use Case 1	A validated and functionally working hardware system that is ready for the implementation of the MPC algorithm	A well-functioning MPC system adapted to the conditions of the test site

Co-funded by the European Union

2	Real-Time System Testing and Performance Evaluation	In this scenario, detailed integration testing of the developed MPC system is performed. During detailed testing, operational limitations are identified and the robustness of the system is enhanced, which is essential for continuous operation.		Completion of system integration and simulation validation	A well-functioning MPC system adapted to the conditions of the test site	A real-time tested, tuned, and evaluated MPC system ready for flexibility service provision under live conditions.

Scenario Name:	System design and implementation							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information Exchanged**	**Requirements (R-ID)**
1.1	Requirement Analysis	Requirement Definition	ME defines control objectives, constraints, and modeling requirements for the MPC system.	Design Specification	Modeling Expert (ME)	Modeling Expert (ME)	Control requirements specification	R-ID-01
1.2	Data Preparation	Data Collection and Cleaning	ME collects and preprocesses input-output data from the prototype system.	Modeling Service	Modeling Expert (ME)	Modeling Expert (ME)	Cleaned datasets	R-ID-02
1.3	System Modeling	System Modeling	ME develops predictive system models using collected data.	Modeling Service	Modeling Expert (ME)	Modeling Expert (ME)	Identified models	R-ID-03
1.4	MPC Problem Formulation	MPC Formulation	ME formulates the optimization problem for the MPC.	Control Design Service	Modeling Expert (ME)	Control Engineer (CE)	Optimization problem formulation	R-ID-04
2.1	MPC Controller Design	Designs the MPC controller	CE designs the controller implementation and control logic for MPC.	Controller Design	Control Engineer (CE)	Modeling Expert (ME)	Design specification	R-ID-04
2.2	Implementation Constraints	Technological limitation and correction	CE communicates implementation limitations; ME adapts the model accordingly.	Model Adaptation	Control Engineer (CE)	Modeling Expert (ME)	Implementation feedback	R-ID-04

Co-funded by the European Union

2.3	Modified Model Delivery	Provide modified MPC model with properly cost function	ME delivers the final MPC model with cost function tailored to system limits.	Modeling Service	Modeling Expert (ME)	Control Engineer (CE)	Modified MPC model	R-ID-04
2.4	MPC Integration	Implement MPC model	CE implements the finalized MPC logic on the target system.	Deployment Service	Control Engineer (CE)	MPC System	Deployed MPC controller	R-ID-04
2.5	Forecast Integration	Implement Forecast Database	CE connects the MPC to the forecast data system.	Integration Service	Control Engineer (CE)	Forecast Database (FD)	Forecast interface	R-ID-04
3.1	Functional Test Definition	Definition of functional test cases	ME defines test scenarios to validate the control system functionality.	Testing Service	Modeling Expert (ME)	Control Engineer (CE)	Test case specification	R-ID-5
3.2	Simulation Execution	Initiate simulation	CE launches test simulations using the implemented MPC.	Simulation Service	Control Engineer (CE)	MPC System	Simulation trigger	R-ID-5
3.3	Simulation Feedback	Send simulated response	MPC provides output from the simulation runs for analysis.	Simulation Output	MPC System	Control Engineer (CE)	Simulation results	R-ID-5

Scenario Name:	**Real-Time System Testing and Performance Evaluation**							
Step No.	Event	Name of Process/ Activity	Description of Process/Activity	Service	Information Producer (Actor)	Information Receiver (Actor)	Information Exchanged	Requirements (R-ID)
2.1	Test Strategy Definition	Definition of Test Strategy	ME defines the testing approach for evaluating real-time MPC performance.	Testing Service	Modeling Expert (ME)	Control Engineer (CE)	Test strategy plan	R-ID-6
2.2	Test Case Definition	Definition of Test Cases	ME provides detailed test cases to verify control logic under real-time conditions.	Testing Service	Modeling Expert (ME)	Control Engineer (CE)	Test case definitions	R-ID-6
2.3	Simulation Initiation	Initiate simulation	CE launches simulation on the prototype MPC using defined scenarios.	Simulation Service	Control Engineer (CE)	Prototype MPC	Simulation trigger	R-ID-6

Co-funded by the European Union

2.4	Data Provision	Provide real-time data	MPC provides live control data during simulation to CE.	Data Exchange Service	Prototype MPC	Control Engineer (CE)	Live performanc e data	R-ID-6
2.5	Paramet er Adjustm ent	Adjust paramete rs	CE adjusts controller parameters based on real-time test feedback.	Tuning Service	Control Engineer (CE)	Prototype MPC	Updated tuning parameters	R-ID-4
2.1	Performa nce Data Collectio n	Collect performa nce data	AN gathers output and system response data from real-time MPC execution.	Evaluatio n Service	Analyst (AN)	Prototype MPC	Operational data logs	R-ID-6
2.2	Evaluatio n Summar y	Generate evaluatio n summary	AN summarizes key performance metrics and system response.	Evaluatio n Service	Analyst (AN)	Evaluation Report	Performanc e summary	R-ID-6
2.3	Report Submissi on	Submit report	Evaluation report is submitted to the Project Manager for review.	Evaluatio n Reporting	Evaluation Report	Project Manager (PM)	Evaluation results	R-ID-6
3.1	Final Docume ntation	Compile final documen tation	PM prepares the complete project documentation including configuration, tuning, and results.	Documen tation Service	Project Manager (PM)	Evaluation Report	Final documentat ion package	R-ID-7

Co-funded by the European Union

3.4.3. UC – HU 3: Integration of Flexibility into MPC and Interaction with DSO

Description of the Use Case

Use case Identification		
ID	**Title**	**Domain**
HU3	Integration of Flexibility into MPC and Interaction with DSO	Energy efficiency and flexibility activation

Version Management			
Version No	**Date**	**Name of authors**	**Changes**
01	15.04.2025		
02	04.05.2025	Péter Grabner (Profigram)	Corrections to clarify the use case. Revision and simplification of roles. Improvement of process transparency.

Classification Information	
Pilot Involved	Hungarian Pilot led by Profigram, Fair C, ÉMI
Relation to Other Use Cases	- UC – HU 2: Control system design and construction - UC – HU 4: Integration of Electric Vehicle Charger into the MPC Framework
Related Innovative SEEDS solutions	Interactive microgrid controller for the flexibility service and current demand of the DSO.
Assets of the UC	MPC

Scope and Objectives of Use Case	
Scope of the use case	The scope of this use case is to expand the capabilities of the Model Predictive Control system developed in the second use case by modeling and exploiting thermal storage in building mass and electrical storage in batteries. The enhanced MPC will now respond not only to internal performance goals (comfort, efficiency, cost) but also to external signals from the DSO, such as price signals or load requests. This will require:

	• Modeling flexibility constraints and dynamic response capabilities, • Integrating DSO data link communication into the control architecture, • Testing the system in scenarios where the MPC reacts to DSO flexibility requests.
Objectives of the use case	1. **Model Flexibility Resources**: Represent the heat storage capacity of building elements and the battery's charge/discharge capabilities within the MPC framework. 2. **DSO Communication Integration**: Use a validated data link to receive flexibility signals or schedules from the DSO. 3. **Design Flexibility-Aware MPC**: Extend the optimization problem to balance local objectives (comfort, energy, cost) with grid-oriented services (e.g., peak shaving, load shifting). 4. **Implement Dynamic Scheduling Logic**: Incorporate DSO signals (e.g., flexibility windows, energy limits) as inputs or constraints in the MPC formulation. 5. **Test Response Scenarios**: Simulate and validate the system's ability to follow DSO commands without violating internal performance criteria. 6. **Evaluate Grid Support Metrics**: Analyze system performance in terms of flexibility delivery, accuracy of tracking DSO signals, and internal trade-offs. 7. **Document Use Case Results**: Provide a detailed report of the test scenarios, model extensions, system behavior, and lessons learned.
Limitations & Assumptions	<u>Limitations</u>: 1. **Thermal Mass Modeling Complexity**: Accurately capturing the dynamics of heat storage in building structures (walls, floors, roof structure) is challenging and may require simplifications that affect precision. 2. **Forecast Dependency**: Flexibility planning depends heavily on accurate forecasts of occupancy, weather, PV generation, and grid signals. Errors in these forecasts can degrade performance. 3. **Battery Degradation and Efficiency**: The MPC does not fully account for battery degradation over time or the variation in round-trip efficiency at different operating points. 4. **Limited DSO Signal Resolution**: Communication delays or low update frequency from the DSO may limit the controller's responsiveness or cause missed flexibility windows. 5. **Multi-Objective Trade-offs**: Balancing internal goals (comfort, cost savings) with external demands (DSO requests) may lead to suboptimal outcomes for one or both objectives.

	6. **Scalability of Control Strategy**: The enhanced MPC may become too complex for real-time computation as more zones, batteries, or DSO constraints are added, especially with nonlinear models. 7. **Standardization of DSO Interfaces**: Lack of standardized protocols or message formats from the DSO can introduce integration difficulties and reduce generalizability to other grid operators. 8. **Control Uncertainty under DSO Constraints**: If DSO signals are uncertain or conflicting (e.g., frequent changes), maintaining system stability and comfort may be compromised. 9. **Limitations of Commercial Hardware**: The controller and sensing infrastructure from Use Case 1 may limit the speed or precision of actuation needed for real-time flexibility. 10. **Regulatory or Market Constraints**: Real-world deployment may be limited by regulatory, economic, or market readiness for residential or small-scale flexibility aggregation. <u>Assumptions</u>: 1. **Reliable DSO Communication**: It is assumed that the data link between the prototype system and the Distribution System Operator (DSO) is stable, secure, and capable of transmitting flexibility requests in a timely manner. 2. **Accurate Building and Battery Models**: The thermal mass and battery models used in the MPC are assumed to be accurate enough to predict system behavior within the prediction horizon. 3. **Known and Fixed System Constraints**: All operational constraints—such as temperature limits, power ratings, and battery SOC bounds—are known and remain constant during each control cycle. 4. **Forecast Data Availability**: Weather forecasts (solar radiation, temperature), PV generation forecasts, and occupancy schedules are assumed to be available and reasonably accurate for the control horizon. 5. **DSO Signal Format and Timing Are Predefined**: The structure, frequency, and semantics of the flexibility requests from the DSO are standardized and known at the time of implementation. 6. Sufficient Computation Capability: The controller hardware has enough processing power to solve the extended MPC problem with the added complexity of flexibility modeling and DSO integration. 7. **No Manual Intervention Required**: Once deployed, the MPC operates autonomously based on incoming data and control objectives, with no need for human intervention during normal operation.

	8. **Comfort and Safety Prioritized**: The system is allowed to prioritize safety (e.g., overheating prevention) and thermal comfort over DSO requests in conflict situations. 9. **Battery Operation Within Safe Limits**: The MPC assumes that battery degradation effects are minimal over the timeframe of testing, and that it can safely operate within manufacturer-recommended charge or discharge cycles. 10. **DSO Requests Are Technically Feasible**: It is assumed that the flexibility requested by the DSO does not exceed the actual physical and thermal limits of the building or the battery system.

Narrative of Use Case	
Short Description	This use case aims to enhance the previously implemented Model Predictive Control (MPC) system by incorporating flexibility from the building's thermal mass and the battery storage system. The upgraded controller is intended to interact with the Distribution System Operator (DSO) via a data communication link, enabling the building to participate in grid-support activities such as demand response, peak shaving, and self-consumption maximization. The MPC will balance internal objectives (e.g., comfort, energy cost) with external signals from the DSO, using flexibility intelligently.
Complete Description	The scope includes modeling the building's passive thermal storage and battery capacity, reformulating the MPC to include grid-oriented flexibility objectives and constraints, integrating data communication with the DSO, and testing the system in simulated and real-time scenarios. This use case is built directly upon: • Use Case 1: where the physical prototype with data communication and sensor infrastructure was developed. • Use Case 2: where an MPC system was deployed to control heating, cooling, and energy use in the building. Now, Use Case 3 introduces external grid signals from the DSO as part of the control logic and aims to co-optimize internal goals (comfort, energy efficiency) and external grid services (flexibility, demand response). *Methodology and Step-by-Step Implementation:* **1. Review and Extension of Existing MPC** • Use the validated MPC framework from Use Case 2. • Identify integration points for flexibility logic. When: At the beginning of Use Case 3

	Why: To ensure consistency with previous control design and reuse existing architecture **2. Modeling of Flexibility** a) Thermal Mass: • It includes heat retention in walls, floors and air. • Add constraints for allowable temperature deviations. b) Battery Storage: Model SOC, power limits, charge/discharge efficiency, and operational constraints. When: After MPC review and baseline confirmation Why: To represent building thermal mass and battery dynamics within the control system **3. Communication with DSO** • Define the format and structure of DSO flexibility signals (e.g., power limits, time windows). • Implement secure and real-time data links using standard protocols. When: After flexibility modeling is defined Why: To enable the MPC to receive and respond to DSO flexibility requests in real time **4. MPC Reformulation** • Extend cost function: include terms for tracking DSO-requested power profile. • Introduce flexibility as a controllable resource. • Add slack variables and comfort penalty mechanisms (if it is necessary). When: Once data link and models are ready Why: To incorporate grid-response objectives and constraints into the controller **5. Forecast Integration** • Use solar radiation, occupancy, and internal heat gain predictions. • Align forecast horizons with control intervals. When: Parallel with MPC reformulation Why: To allow the MPC to make predictive decisions using solar, occupancy, and DSO forecasts **6. Simulation and Validation** • Test the system in virtual scenarios using synthetic DSO signals. • Evaluate how well the MPC balances internal and external goals. When: After the reformulated MPC is complete Why: To test and verify the MPC behavior in synthetic and real-world flexibility scenarios **7. Hardware Deployment**

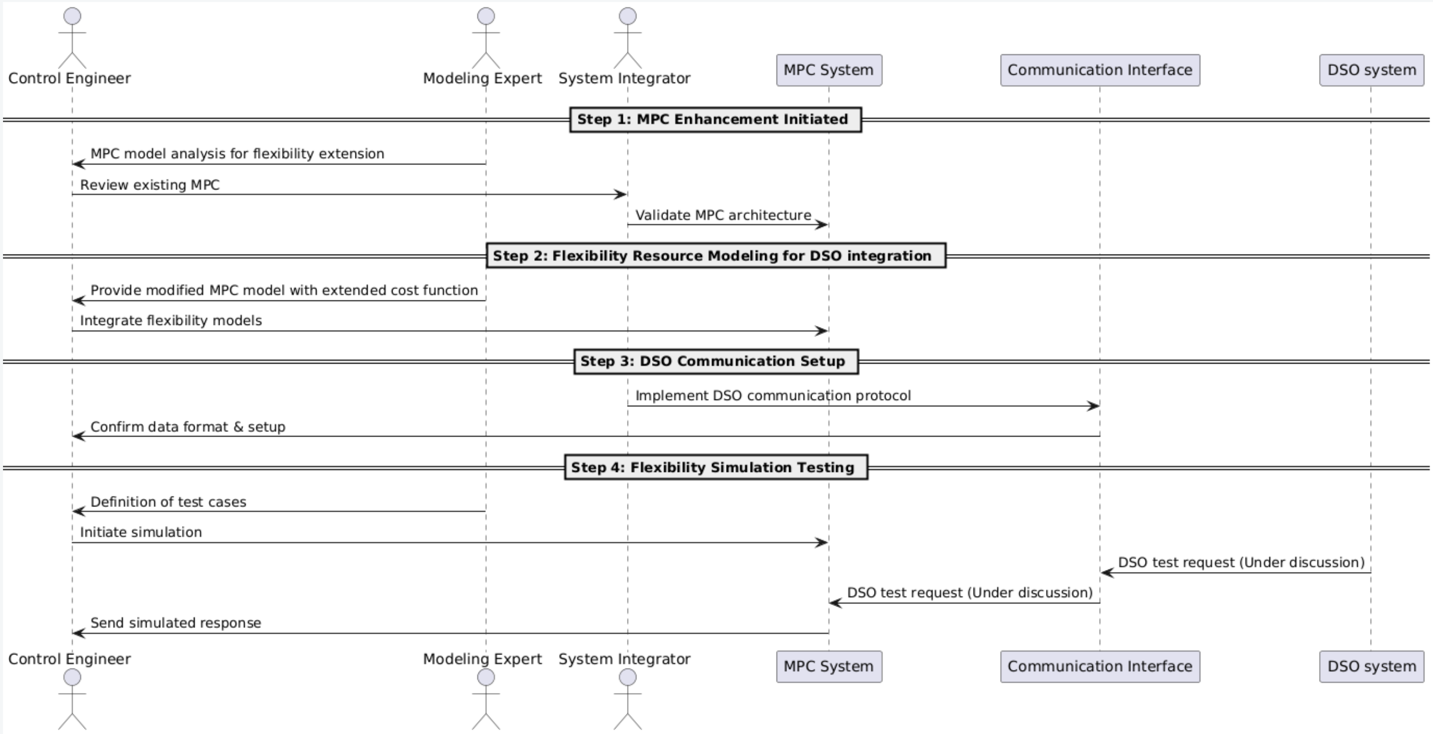
	• Deploy the upgraded MPC on the physical controller (e.g., PLC or industrial PC). • Interface it with the building system and DSO data link. When: After successful simulation validation Why: To bring the enhanced MPC into the real-time control loop of the physical prototype **8. Online Testing and Parameter Tuning** • Perform real-time tests with live or emulated DSO input. • Tune penalty weights, response time, and comfort bounds for balanced performance. When: Following deployment in real environment Why: To refine MPC settings (weights, constraints) for practical system behavior and responsiveness **9. Performance Evaluation** Metrics: • Flexibility tracking accuracy • Comfort preservation • Energy cost reduction • Battery usage efficiency When: After sustained operation under live conditions Why: To assess system behavior, flexibility tracking, comfort preservation, and efficiency **10. Documentation** Deliver full documentation covering: • Model parameters • Control structure • DSO interface • Performance results and tuning settings When: Upon completion of testing and evaluation Why: To ensure reproducibility, enable replication, and prepare for potential scale-up Expected Results: • A fully integrated MPC system that balances comfort, energy efficiency, and DSO interaction. • Demonstrated capability of the building to offer flexibility via thermal mass and battery storage. • Valuable insights into future grid-interactive buildings and scalability pathways.

General Remarks
Negotiations with the DSO have not yet been finalized. They have had to be restarted due to the replacement of a consortium member and the framework for the relationship with the DSO may therefore change. Primary Actor roles do not necessarily mean a separate team member. This is currently being clarified.

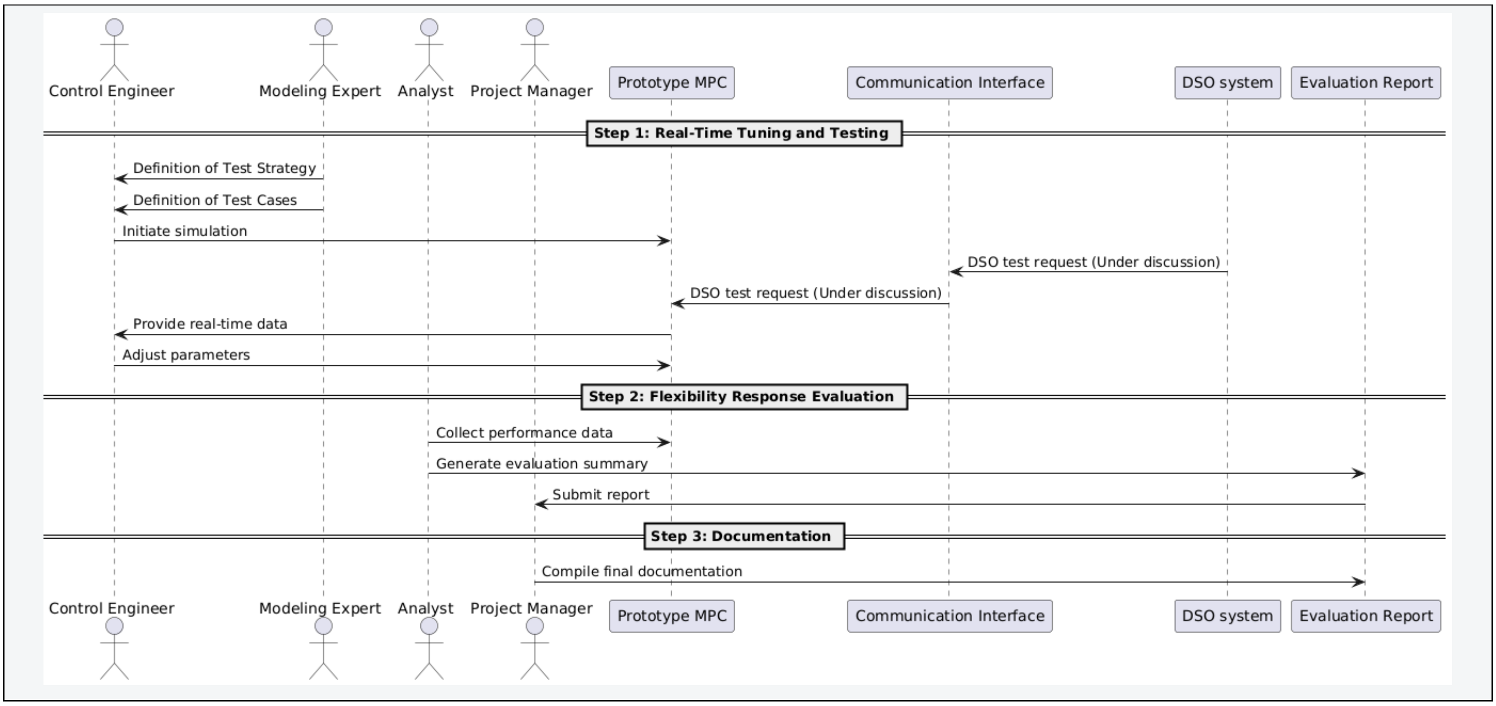
Diagrams of the UC

Sequence diagram of the use case

System Integration and Flexibility Setup:



Real-Time System Testing and Performance Evaluation for Flexibility:



Technical Details of the UC

Actor Name	Actor Type	Actor Description	Further Information Specific to this Use Case
Control Engineer	Human	Designs and updates the MPC logic to incorporate flexibility from thermal mass and battery systems.	Responsible for balancing internal objectives (comfort, efficiency) with external grid signals.
Modeling Expert	Human	Develops models for thermal dynamics and battery systems used in the predictive control logic.	Ensures that thermal mass and battery flexibility are accurately represented for control decision-making.
Data Analyst	Human	Tests and validates the performance of the integrated system.	Runs simulations and real-time tests to verify correct charger control behavior.
System Integrator	Human	Implements and deploys the MPC algorithm in the prototype hardware system.	Connects sensors, actuators, and DSO communication infrastructure.
Project Manager	Human	Oversee the entire use case workflow, including coordination, milestones, and reporting.	Coordinates integration between control team, DSO, and testing stakeholders.

Co-funded by the European Union

MPC Controller	Software Module	Compute optimal control decisions using system models, forecasts, and DSO inputs.	Optimizes power flows, temperature setpoints, and battery usage based on system constraints and grid signals.
Communication Interface	System Component	The middleware or gateway enabling real-time data exchange with the DSO.	Translates and transmits signals between the MPC and external grid operator using standard protocols.
Distribution System Operator (DSO)	External System	Sends flexibility requests and schedules to the building system.	Communicates constraints, load reduction signals, or tariffs via the established data link.
Evaluation Report	Document	Summary document for the scenario	This document summarizes the conceptual, implementation, and testing plans for the scenario, as well as the testing and tuning results.

Step-by-step analysis of use case

Overview of scenarios

Scenario Conditions						
No	**Scenario Title**	**Scenario Description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1	System Integration and Flexibility Setup	This scenario covers the integration of new flexibility resources into the existing MPC framework and establishing communication with the DSO. The aim is to prepare the system for real-time flexibility operation by enhancing models, communication links, and control structures.	Control Engineer, Modeling Expert, System Integrator, Data Analyst	Start of Use Case 3	Validated MPC system from Use Case 2 is available.	An extended MPC system capable of receiving DSO signals and managing flexibility resources in simulation environments.
2	Real-Time System Testing and Performance Evaluation for Flexibility	This scenario involves the deployment of the flexibility-enabled MPC on the prototype system, real-time testing using live or emulated DSO signals, tuning of the controller parameters, and performance	System Integrator, Test Engineer, Analyst, Project Manager	Completion of system integration and simulation validation	Validated MPC performance in simulation; operational prototype platform	A real-time tested, tuned, and evaluated MPC system ready for flexibility service

Co-funded by the European Union

		evaluation based on system behavior and flexibility delivery metrics.				provision under live conditions.

Scenario Name:	**System Integration and Flexibility Setup**							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information Exchanged**	**Requirements (R-ID)**
1.1.1	MPC Model Analysis	MPC model analysis for flexibility	ME analyzes the MPC model for potential flexibility extension.	Control Design Review	Modeling Expert (ME)	Control Engineer (CE)	Preliminary MPC model insights	R-ID-01
1.1.2	Review of Existing MPC	Review existing MPC	CE reviews the existing MPC system for integration readiness.	Control Design Review	Control Engineer (CE)	System Integrator (SI)	Validated MPC structure	R-ID-01
1.1.3	Architecture validation	Validate MPC architecture	SI validates and confirms the baseline MPC architecture.	Control Design Review	System Integrator (SI)	MPC System	Baseline configuration confirmation	R-ID-01
1.2.1	Flexibility Model Delivery	Provide modified MPC model with extended cost function	ME provides updated MPC model, including flexibility logic and cost function extensions.	Modeling Service	Modeling Expert (ME)	Control Engineer (CE)	Extended MPC model	R-ID-02
1.2.2	Model Integration	Integrate flexibility models	CE integrates the flexibility models into the MPC system.	Modeling Service	Control Engineer (CE)	MPC System	Thermal/Battery flexibility model data	R-ID-02
1.3.1	Comm Protocol Implementation	Implement DSO communication protocol	SI implements the real-time DSO communication protocol into the interface.	Communication Service	System Integrator (SI)	Communication Interface (CI)	Protocol implementation data	R-ID-03
1.3.2	Comm Format Confirmation	Confirm data format & setup	CI confirms the communication format and system integration setup.	Communication Service	Communication Interface (CI)	Control Engineer (CE)	Protocol configuration confirmation	R-ID-03

Co-funded by the European Union

1.4.1	Test Case Definition	Definition of test cases	ME defines the simulation test cases required for flexibility evaluation.	Simulation Service	Modeling Expert (ME)	Control Engineer (CE)	Test case definitions	R-ID-04
1.4.2	Simulation Initiation	Initiate simulation	CE initiates MPC simulation based on test cases.	Simulation Service	Control Engineer (CE)	MPC System	Simulation start signal	R-ID-04
1.4.3	DSO Test Request	DSO test request (Under discussion)	DO sends a flexibility test request (preliminary phase).	DSO Request Service	DSO System (DO)	Communication Interface (CI)	DSO test request	R-ID-04
1.4.4	Forward DSO Request	DSO test request (Under discussion)	CI forwards DSO test request to MPC.	Communication Service	Communication Interface (CI)	MPC System	DSO test request relay	R-ID-04
1.4.5	Simulation Response	Send simulated response	MPC sends the simulation result to the Control Engineer.	MPC Response Service	MPC System	Control Engineer (CE)	Simulated flexibility response	R-ID-04

Scenario Name:	Real-Time System Testing and Performance Evaluation for Flexibility							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information Exchanged**	**Requirements (R-ID)**
2.1.1	Test Strategy Definition	Definition of Test Strategy	ME defines the testing approach for evaluating real-time system behavior.	Testing Service	Modeling Expert (ME)	Control Engineer (CE)	Test strategy plan	R-ID-05
2.1.2	Test Case Definition	Definition of Test Cases	ME provides detailed test cases for flexibility testing.	Testing Service	Modeling Expert (ME)	Control Engineer (CE)	Test cases	R-ID-05
2.1.3	Simulation Initiation	Initiate simulation	CE initiates simulation on the prototype MPC.	Testing Service	Control Engineer (CE)	Prototype MPC	Simulation trigger	R-ID-05
2.1.4	DSO Test Request	DSO test request (Under discussion)	DSO sends test flexibility request to the system.	DSO Request Service	DSO System (DO)	Communication Interface (CI)	DSO flexibility request	R-ID-05
2.1.5	Forward DSO Request	DSO test request (Under discussion)	CI forwards the DSO flexibility request to the MPC system.	Communication Service	Communication Interface (CI)	Prototype MPC	Forwarded DSO test request	R-ID-05

Co-funded by the European Union

2.1.6	Real-Time Data Provision	Provide real-time data	MPC provides live data during testing to CE.	Testing Service	Prototype MPC	Control Engineer (CE)	Live performance data	R-ID-05
2.1.7	Parameter Tuning	Adjust parameters	CE adjusts MPC parameters based on testing observations.	Testing Service	Control Engineer (CE)	Prototype MPC	Updated parameters	R-ID-05
2.2.1	Data Collection	Collect performance data	Analyst collects output data from MPC operation.	Evaluation Service	Analyst (AN)	Prototype MPC	Operational data	R-ID-06
2.2.2	Evaluation Summary	Generate evaluation summary	Analyst compiles and analyzes the test performance results.	Evaluation Service	Analyst (AN)	Evaluation Report	Performance summary	R-ID-06
2.2.3	Submit Report	Submit report	Evaluation report is submitted to the Project Manager.	Evaluation Service	Evaluation Report	Project Manager (PM)	Evaluation results	R-ID-06
2.3.1	Final Documentation	Compile final documentation	Project Manager prepares and finalizes the documentation package.	Documentation Service	Project Manager (PM)	Evaluation Report	Final documentation	R-ID-7

3.4.4. UC – HU 4: Integration of Electric Vehicle Charger into the MPC Framework

Description of the Use Case

Use case Identification		
ID	**Title**	**Domain**
HU4	Integration of Electric Vehicle Charger into the MPC Framework	Smart Electric Mobility

Version Management			
Version No	**Date**	**Name of authors**	**Changes**
01	15.04.2025	Péter Grabner (Profigram)	
02	04.05.2025	Péter Grabner	Corrections to clarify the use case. Revision and simplification of roles. Improvement of process transparency.

Classification Information	
Pilot Involved	Hungarian Pilot led by Profigram,
Relation to Other Use Cases	- UC – HU 1: Setting up and testing the system to be deployed - UC – HU 2: Control system design and construction - UC – HU 3: Integration of Flexibility into MPC and Interaction with DSO
Related Innovative SEEDS solutions	Microgrid controller for PV production, storage and consumption of the VRV, for optimal operation and maximizing RES
Assets of the UC	PV, storage, EV charger, MPC

Co-funded by the European Union

Scope and Objectives of Use Case	
Scope of the use case	This use case involves the integration of an EV charger model into the building's control framework. The EV charger will be treated as an additional controllable load, and its operation will be optimized together with existing building elements such as thermal mass, battery storage, and PV generation. The control algorithm will ensure that the vehicle is charged according to the user's needs while maximizing cost efficiency, minimizing grid stress, and responding to DSO flexibility signals.
Objectives of the use case	1. Model the EV charging process, including battery size, charging rate, and user-defined departure times. 2. Integrate EV charging into the MPC optimization problem. 3. Coordinate EV charging with other flexible assets (thermal mass, battery, PV). 4. Respect grid constraints and respond to DSO signals during charging periods. 5. Ensure the vehicle meets the desired state of charge (SOC) by departure time.
Limitations & Assumptions	Limitations: 1. Limited data availability for real-time EV user behavior and arrival/departure schedules. 2. Nonlinear battery charging characteristics may require simplification. 3. Grid signals may conflict with mobility requirements. 4. Additional computational load for real-time optimization. 5. Assuming only one EV is present; scaling to multiple vehicles not addressed here. Assumptions: 1. EV availability and user requirements (arrival time, departure time, desired SOC) are known. 2. The charger and its power limits are compatible with the control system. 3. Communication with the EV charger is reliable and timely. 4. Forecast data and flexibility signals are integrated as in previous use cases. 5. Cost signals (e.g., time-of-use tariffs) are known in advance.

Co-funded by
the European Union

Narrative of Use Case	
Short Description	This use case extends the existing Model Predictive Control (MPC) framework by incorporating an electric vehicle (EV) charging station into the control model. The system will optimize EV charging schedules in coordination with building loads, battery storage, thermal flexibility, PV production, and DSO flexibility requests. The goal is to manage charging in a way that balances grid support, self-consumption, energy cost reduction, and user-defined mobility requirements.
Complete Description	*Methodology and Step-by-Step Implementation:* 1. **EV Charger Modeling:** Define charging power limits, SOC dynamics, and efficiency. Include constraints based on user departure time and minimum required SOC, PV generation and electricity pricing When: At the beginning of Use Case 4 Why: To understand the charging power profile and system limitations 2. **Integration into MPC:** Add EV charging as a control input and SOC as a state variable. Include cost, comfort, and flexibility objectives. When: After charger modeling is complete Why: To allow predictive optimization of charging within the MPC framework 3. **Simulation and Testing:** Validate controller logic in simulation. Tune for performance under varying user needs and grid signals. When: After integration and forecast setup Why: To validate and tune the controller before real-time deployment 4. **Real-Time Deployment:** Implement on prototype hardware. Monitor performance, adapt tuning, and document results. When: Once simulations are successful Why: To evaluate real-time performance with real energy and mobility demands 6. **Documentation** Deliver full documentation covering: • Model parameters • Performance results and tuning settings When: Upon completion of real-time deployment Why: To ensure reproducibility, enable replication, and prepare for potential scale-up

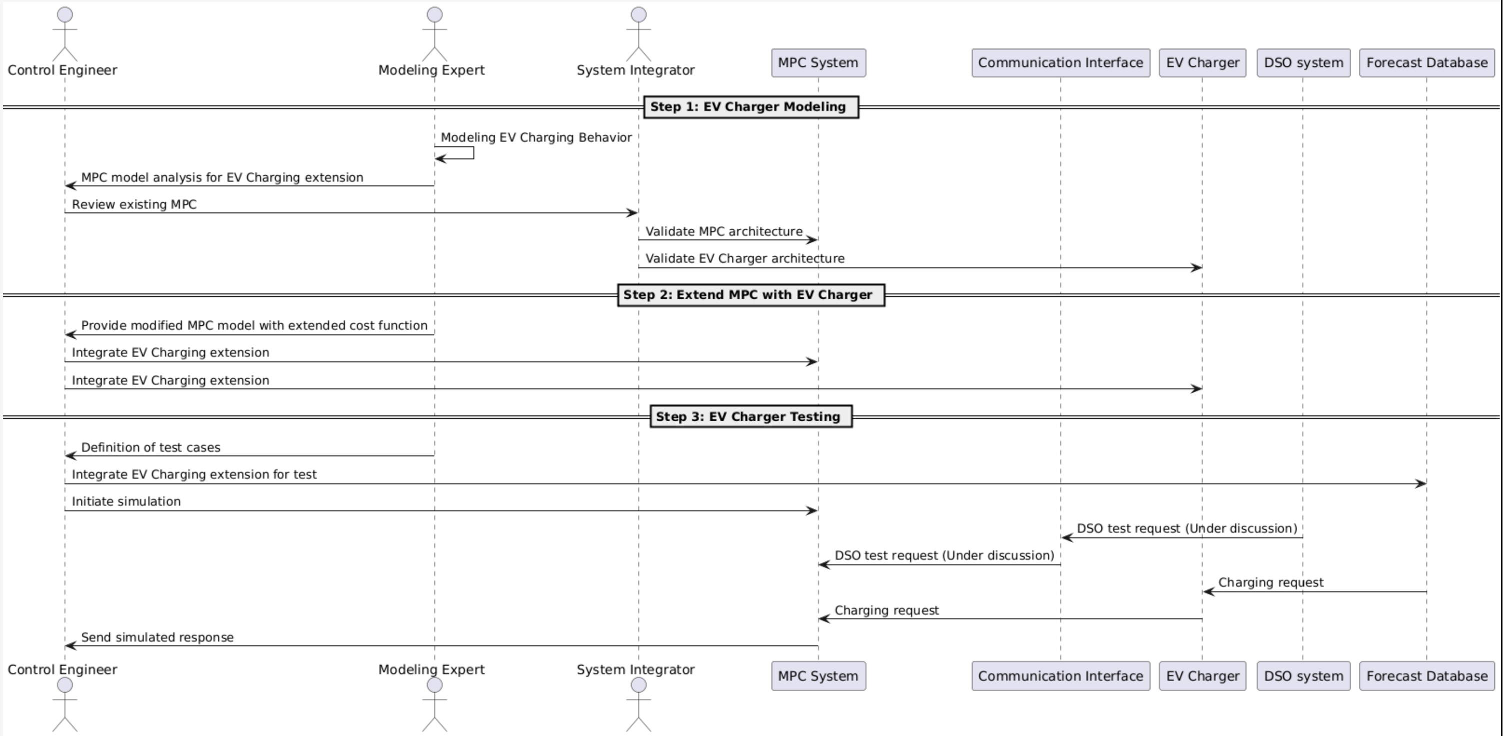
	Expected Results: The MPC system successfully integrates the EV charger into the existing control framework, enabling real-time scheduling of charging sessions in coordination with building loads, PV generation, battery storage, and thermal flexibility.

General Remarks
Primary Actor roles do not necessarily mean a separate team member. This is currently being clarified.

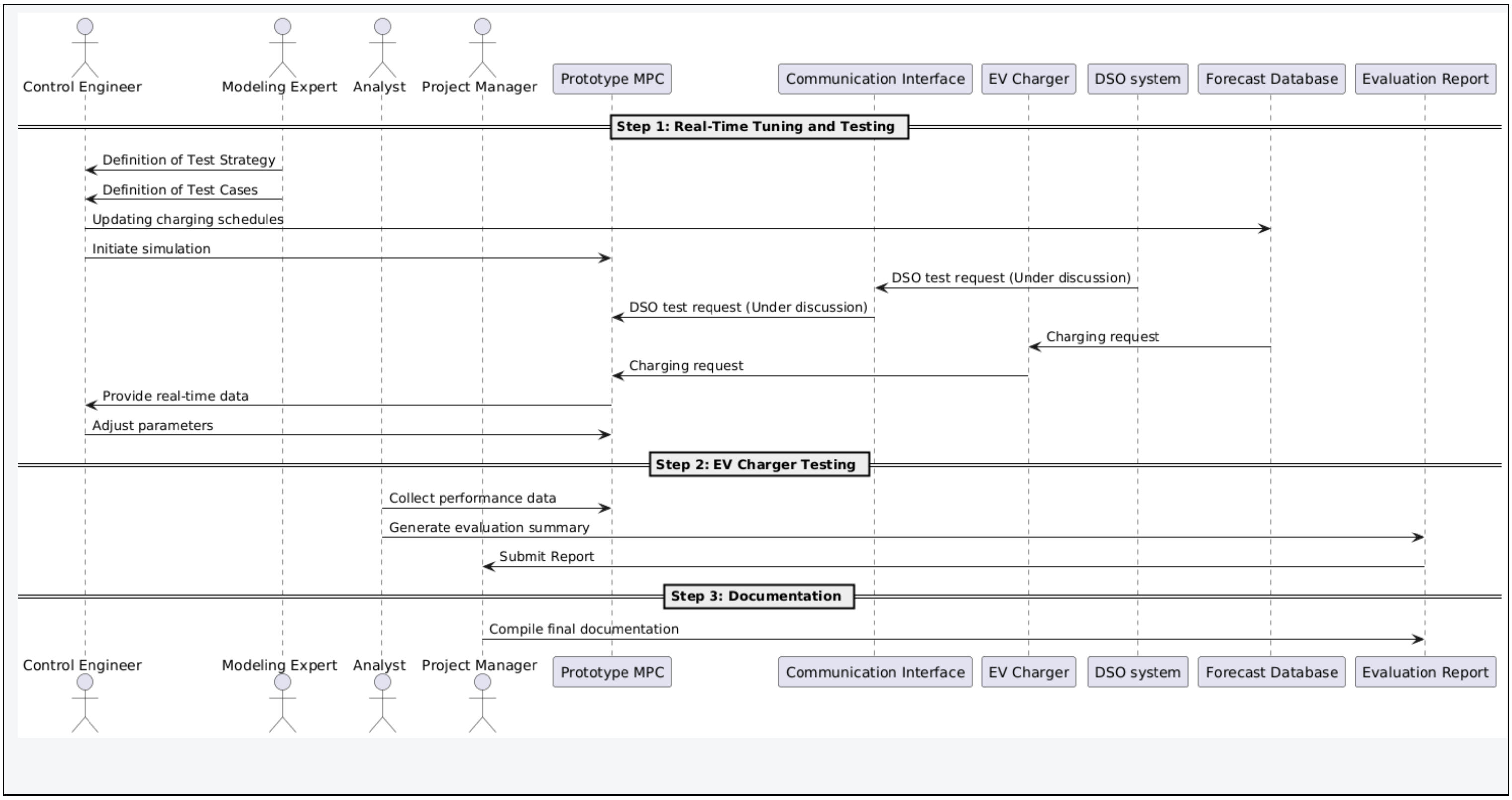
Diagrams of the UC

Sequence diagram of the use case

EV Charger Integration and MPC Extension:



Real-Time EV Charging Control and Performance Evaluation:



Technical Details of the UC

Actor Name	Actor Type	Actor Description	Further Information Specific to this Use Case
Control Engineer	Human	Designs and extends the MPC logic to incorporate EV charging.	Ensures data exchange between the charger, control algorithm, and DSO interfaces.
Modeling Expert	Human	Develops MPC model modification for EV charging process	Responsible for formulating the optimization problem with EV SOC, timing, and energy costs in mind.
Data Analyst	Human	Tests and validates the performance of the integrated system.	Runs simulations and real-time tests to verify correct charger control behavior.
Project Manager	Human	Coordinates the integration and deployment phases.	Oversees technical milestones, documentation, and inter-team collaboration.

EV Charger	System Resource	Electric vehicle supply equipment (EVSE) executing the charging schedule.	Acted upon by the control system to follow optimized charging profiles.
MPC Controller	Software Module	Computes optimal control actions based on constraints, costs, and forecasts.	Integrates EV charging with other controllable systems while satisfying user needs.
Communication interface	Software Module	The middleware or gateway enabling real-time data exchange with the DSO.	Translates and transmits signals between the MPC and external grid operator using standard protocols.
DSO (Distribution System Operator)	External System	May provide flexibility signals or time-of-use tariff information.	Sends signals that may influence the timing and rate of EV charging.
Forecast Database	Software Module	This database stores external data used by MPC.	Various car charging scenarios are required for testing purposes. These scenarios are stored here.
Evaluation Report	Document	Summary document for the scenario	This document summarizes the conceptual, implementation, and testing plans for the scenario, as well as the testing and tuning results.

Step-by-step analysis of use case

Overview of scenarios

Scenario Conditions						
No	**Scenario Title**	**Scenario Description**	**Primary Actor**	**Triggering Event**	**Pre-condition**	**Post-condition**
1.	EV Charger Integration and MPC Extension	This scenario focuses on the process of incorporating the EV charger into the existing MPC framework, including the modeling of EV charger characteristics and the extension of the optimization problem to include charging schedules.			A well-functioning MPC system capable of processing DSO requests	MPC system with added EV charging management
2.	Real-Time EV Charging Control and Performance Evaluation	After integrating the EV charger into the MPC system, this scenario focuses on real-time testing, performance evaluation, and adjustments to ensure that the charging process works efficiently under varying grid and user conditions.			MPC system with added EV charging management	A tested and properly functioning MPC system that efficiently manages the power requirements of EV charger under various assumptions.

Scenario Name:	**EV Charger Integration and MPC Extension**							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information Exchanged**	**Requirements (R-ID)**
1.1.1	EV Charger Modeling	Modeling EV Charging Behavior	ME defines EV charging dynamics including power limits, SOC, efficiency, and timing constraints.	Modeling Service	Modeling Expert (ME)	Modeling Expert (ME)	EV Charging Model	R-ID-01
1.1.2	Model Analysis	MPC model analysis for EV Charging extension	ME shares insights on how to extend MPC with EV charger model.	Modeling Service	Modeling Expert (ME)	Control Engineer (CE)	Extended modeling requirements	R-ID-01

Co-funded by the European Union

1.1.3	Review of Existing MPC	Review existing MPC	CE reviews the current MPC model for compatibility with EV integration.	Control Design Review	Control Engineer (CE)	System Integrator (SI)	Review results	R-ID-01
1.1.4	Validate MPC Architecture	Validate MPC architecture	SI validates the existing MPC implementation for EV compatibility.	Deployment Service	System Integrator (SI)	MPC System	Validated MPC architecture	R-ID-01
1.1.5	Validate EV Charger	Validate EV Charger architecture	SI validates the EV charger integration with the control framework.	Deployment Service	System Integrator (SI)	EV Charger	Validated charger configuration	R-ID-01
1.2.1	MPC Model Delivery	Provide modified MPC model with extended cost function	ME delivers an MPC model extended with EV cost and flexibility logic.	MPC Extension Service	Modeling Expert (ME)	Control Engineer (CE)	Modified MPC model	R-ID-02
1.2.2	MPC Update	Integrate EV Charging extension	CE integrates EV charging into MPC logic and control flow.	MPC Extension Service	Control Engineer (CE)	MPC System	EV control variables and constraints	R-ID-02
1.2.3	EV Logic Update	Integrate EV Charging extension	CE updates the EV Charger with MPC-compatible control logic.	MPC Extension Service	Control Engineer (CE)	EV Charger	Control signals and logic	R-ID-02
1.3.1	Define Test Cases	Definition of test cases	ME defines test cases to validate the EV charging control logic.	Simulation Service	Modeling Expert (ME)	Control Engineer (CE)	EV test cases	R-ID-03
1.3.2	Forecast Integration	Integrate EV Charging extension for test	CE integrates forecast and user schedule data for testing.	Forecasting Service	Control Engineer (CE)	Forecast Database (FD)	User schedule and forecast	R-ID-03
1.3.3	Start Simulation	Initiate simulation	CE initiates a simulation with the integrated EV model.	Simulation Service	Control Engineer (CE)	MPC System	Simulation trigger	R-ID-03
1.3.4	DSO Request	DSO test request (Under discussion)	DSO sends test flexibility signal to the system.	DSO Request Service	DSO System (DO)	Communication Interface (CI)	DSO test signal	R-ID-03
1.3.5	Forward DSO Request	DSO test request (Under	CI forwards the DSO request to the MPC system.	Communication Service	Communication Interface (CI)	MPC System	Forwarded DSO test signal	R-ID-03

Co-funded by the European Union

		discussion)						
1.3.6	EV Charging Request	Charging request	Forecast system requests EV charging based on forecasted usage.	Forecasting Service	Forecast Database (FD)	EV Charger	Charging command	R-ID-03
1.3.7	EV-MPC Communication	Charging request	EV charger communicates charging request to MPC.	Control Data Exchange	EV Charger	MPC System	Charging status	R-ID-03
1.3.8	Simulation Response	Send simulated response	MPC provides simulated response to CE.	MPC Response Service	MPC System	Control Engineer (CE)	Simulation result	R-ID-03

Scenario Name:	**Real-Time EV Charging Control and Performance Evaluation**							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information Exchanged**	**Requirements (R-ID)**
2.1.1	Test Strategy Definition	Definition of Test Strategy	ME defines the testing approach for evaluating real-time EV charging behavior.	Testing Service	Modeling Expert (ME)	Control Engineer (CE)	Test strategy plan	R-ID-04
2.1.2	Test Case Definition	Definition of Test Cases	ME provides detailed test cases for EV charging control evaluation.	Testing Service	Modeling Expert (ME)	Control Engineer (CE)	Test cases	R-ID-04
2.1.3	Charging Schedule Update	Updating charging schedules	CE updates the EV charging schedules using forecast and user input.	Forecasting Service	Control Engineer (CE)	Forecast Database (FD)	Updated charging schedule	R-ID-04
2.1.4	Simulation Initiation	Initiate simulation	CE initiates simulation on the prototype MPC with updated schedules.	Testing Service	Control Engineer (CE)	Prototype MPC	Simulation trigger	R-ID-04
2.1.5	DSO Test Request	DSO test request (Under discussion)	DSO sends a test flexibility signal to the system.	DSO Request Service	DSO System (DO)	Communication Interface (CI)	DSO flexibility request	R-ID-04
2.1.6	Forward DSO Request	DSO test request (Under	CI forwards the DSO flexibility request to the MPC system.	Communication Service	Communication Interface (CI)	Prototype MPC	Forwarded DSO test request	R-ID-04

		discussion)						
2.1.7	EV Charging Request	Charging request	Forecast system sends a charging command to the EV charger.	Forecasting Service	Forecast Database (FD)	EV Charger	Charging command	R-ID-04
2.1.8	EV-MPC Communication	Charging request	EV charger communicates charging request to MPC.	Control Data Exchange	EV Charger	Prototype MPC	Charging status	R-ID-04
2.1.9	Real-Time Data Provision	Provide real-time data	MPC provides live data during testing to CE.	Testing Service	Prototype MPC	Control Engineer (CE)	Live performance data	R-ID-04
2.1.10	Parameter Tuning	Adjust parameters	CE adjusts MPC parameters based on testing observations.	Testing Service	Control Engineer (CE)	Prototype MPC	Updated parameters	R-ID-04
2.2.1	Data Collection	Collect performance data	Analyst collects output data from MPC operation.	Evaluation Service	Analyst (AN)	Prototype MPC	Operational data	R-ID-05
2.2.2	Evaluation Summary	Generate evaluation summary	Analyst compiles and analyzes the test performance results.	Evaluation Service	Analyst (AN)	Evaluation Report	Performance summary	R-ID-05
2.2.3	Submit Report	Submit report	Evaluation report is submitted to the Project Manager.	Evaluation Service	Evaluation Report	Project Manager (PM)	Evaluation results	R-ID-05
2.3.1	Final Documentation	Compile final documentation	Project Manager prepares and finalizes the documentation package.	Documentation Service	Project Manager (PM)	Evaluation Report	Final documentation	R-ID-06

Co-funded by
the European Union

3.5. USE CASES OF SLOVENIAN PILOT (SL)

3.5.1. UC – SL 1: Capturing of telemetry data

Description of the Use Case

Use case Identification		
ID	**Title**	**Domain**
SL1	Capturing of telemetry data	Data Management, Visualization

Version Management			
Version No	**Date**	**Name of authors**	**Changes**
01	11.11.2024	Erik Gramc (Petrol)	First proposal of use case
02	01.04.25	Tsompanidou Eleni (CERTH)	Review

Classification Information	
Pilot Involved	Slovenian pilot, led by Petrol with support by JSI and ELCE
Relation to Other Use Cases	- UC – SL 2: Providing flexibility services
Related Innovative SEEDS solutions	- Digital platform connecting BMS and real-time electricity prices - Data quality assurance mechanism
Assets of the UC	Five gas stations owned and operated by Petrol; each including electrified devices, sensor and communication equipment, modeling and optimization algorithms running on a dedicated server and a decision support system.

Scope and Objectives of Use Case	
Scope of the use case	The scope of the use case refers to the capture of data from devices on pilot facilities, as part of the input data for the implementation of the real-time adaptability service.
Objectives of the use case	• Develop collectors for data collection • Develop an agent for entering data into the database • Implement the solution on a Slovenian pilot

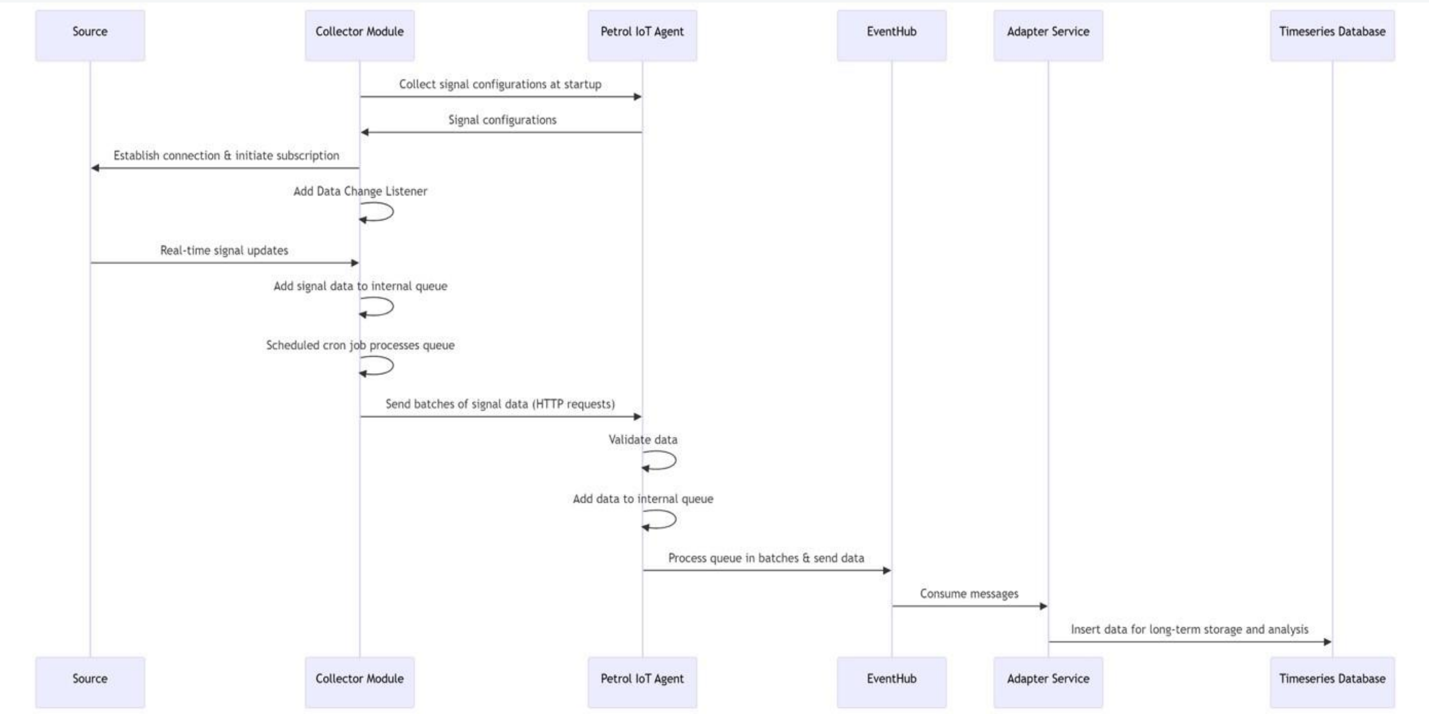
Co-funded by
the European Union

	• Verify the credibility and reliability of the data collection
Limitations & Assumptions	Reliable real-time data capture requires a stable network, otherwise the data may arrive in the system with a delay.

Narrative of Use Case	
Short Description	The Collector Module connects to the source, collects signal configurations from the Petrol agent, subscribes to signals, and uses a listener to add real-time data to an internal queue.
Complete Description	The Collector Module and Petrol IoT Agent work collaboratively to ensure the smooth collection, validation, and storage of real-time signal data in a timeseries database. **Collector Module Workflow:** Upon startup, the Collector module establishes a connection to the source and initiates a managed subscription (for OPC data collection). A Data Change Listener is added to track real-time signal updates. The module collects signal configurations for the source from the Petrol agent and subscribes to signals as needed. Any changes in signal data are captured by the listener, which adds them to an internal queue within the Collector module. A scheduled cron job processes the internal queue periodically, sending batches of signal data to the Petrol IoT Agent. This approach optimizes resource usage and ensures efficient data transmission. **Petrol IoT Agent Workflow:** The agent receives data from the Collector module via HTTP requests. Before processing, the agent validates the data by checking whether the module and its signals are active and correctly configured. After validation, the agent adds the received data to its internal queue. To prevent flooding the EventHub topic, the agent processes the queue in batches, sending multiple data entries in a single message. Once the data is sent to EventHub, an adapter service consumes the messages and inserts them into a timeseries database for long-term storage and analysis. **Interaction Between Collector Module and Petrol IoT Agent:** The Collector module ensures the continuous and reliable collection of signal data from the source. It serves as the initial source of truth for signal updates, which it sends to the Petrol IoT Agent. The Petrol IoT Agent acts as the intermediary, validating and batching the data from multiple modules (like the Collector) before transmitting it to EventHub for centralized processing and storage. Both services work together to ensure efficient data flow, prevent system overloads, and support functionalities like historical data retrieval. This integrated approach ensures real-time monitoring, efficient resource

	utilization, and scalable data management for IoT systems in the energy sector.

Diagrams of the UC

Sequence diagram of the use case


Technical Details of the UC

Actors			
Actor Name	**Actor Type**	**Actor Description**	**Further information specific to this Use Case**
Data Collector Module	Software	Collects signal configuration and signal data.	N/A
IoT Agent	Software	Validates the data.	N/A
IoT Platform	Software	User Interface	N/A
Adapter service	Software	Reads data from Eventhub and writes them to DB	N/A
EventHub	Software	Streaming engine	N/A

Step-by-step analysis of use case

Overview of scenarios

Scenario Conditions						
No	**Scenario title**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-Condition**
S01	Data capture	Providing telemetry data for flexibility service	Prosumer	DSO sends the prosumer request for electricity flexibility	DSO and prosumer are connected with the SEEDS FSS; SEEDS FSS is operational; DSO and prosumer have an active contract for flexibility services.	None

Steps per scenario

Scenario Name	S01 – "Data capture"							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
St1	Request for reading a new signal	Reading data	User defines a new signal	IoT Platform UI	IoT Platform	IoT Platform	None	Operational IoT Platform
St2	Data Collector synchronize Configuratio	Configuration synchronization	Configuration synchronization	Data Collector Module Service	Data Collector Module	Data Collector Module	None	Operational Data Collector Module

	n of the Signal							
St3	Reading data	Reading data	Reading data	Data Collector Module Service	Data Collector Module	Data Collector Module	None	Operational Data Collector Module
St4	Data validation	Data validation	Data validation	Petrol IoT Agent Service	Petrol IoT Agent	Petrol IoT Agent	None	Operational Petrol IoT Agent
St5	Writing data to EventHub	Writing data	Writing data to EventHub	Petrol IoT Agent Service	Petrol IoT Agent	Petrol IoT Agent	None	Operational Petrol IoT Agent
St6	Adapter Service reads data from Eventhub and write it to DB	Writing data to DB	Writing data to Timescale DB	Adapter Service	Adapter Service	Adapter Service	None	Operational Adapter Service

3.5.2. UC – SL 2: Providing flexibility services

Description of the Use Case

Use case Identification		
ID	**Title**	**Domain**
SL2	Providing flexibility services	DER, Flexibility Services

Version Management			
Version No	**Date**	**Name of authors**	**Changes**
01	02.9.2024	Bernard Ženko (JSI)	First proposal of use case
02	01.04.2024	Eleni Tsompanidou (CERTH)	Review of the Use case
03	04.04.2025	Bernard Ženko (JSI)	Final

Classification Information	
Pilot Involved	Slovenian pilot, led by Petrol with support by JSI and ELCE
Relation to Other Use Cases	- UC – SL 1: Capturing of telemetry data Five gas stations owned and operated by Petrol; each including electrified devices, sensor and communication equipment, modeling and optimization algorithms running on a dedicated server and a decision support system.
Related Innovative SEEDS solutions	– Multi-criteria characterization models of micro energy sources – Multi-objective optimization and aggregation for energy flexibility – Decision support system for market bidding of electricity balancing services
Assets of the UC	Five gas stations owned and operated by Petrol; each including electrified devices, sensor and communication equipment, modeling and optimization algorithms running on a dedicated server and a decision support system.

Co-funded by the European Union

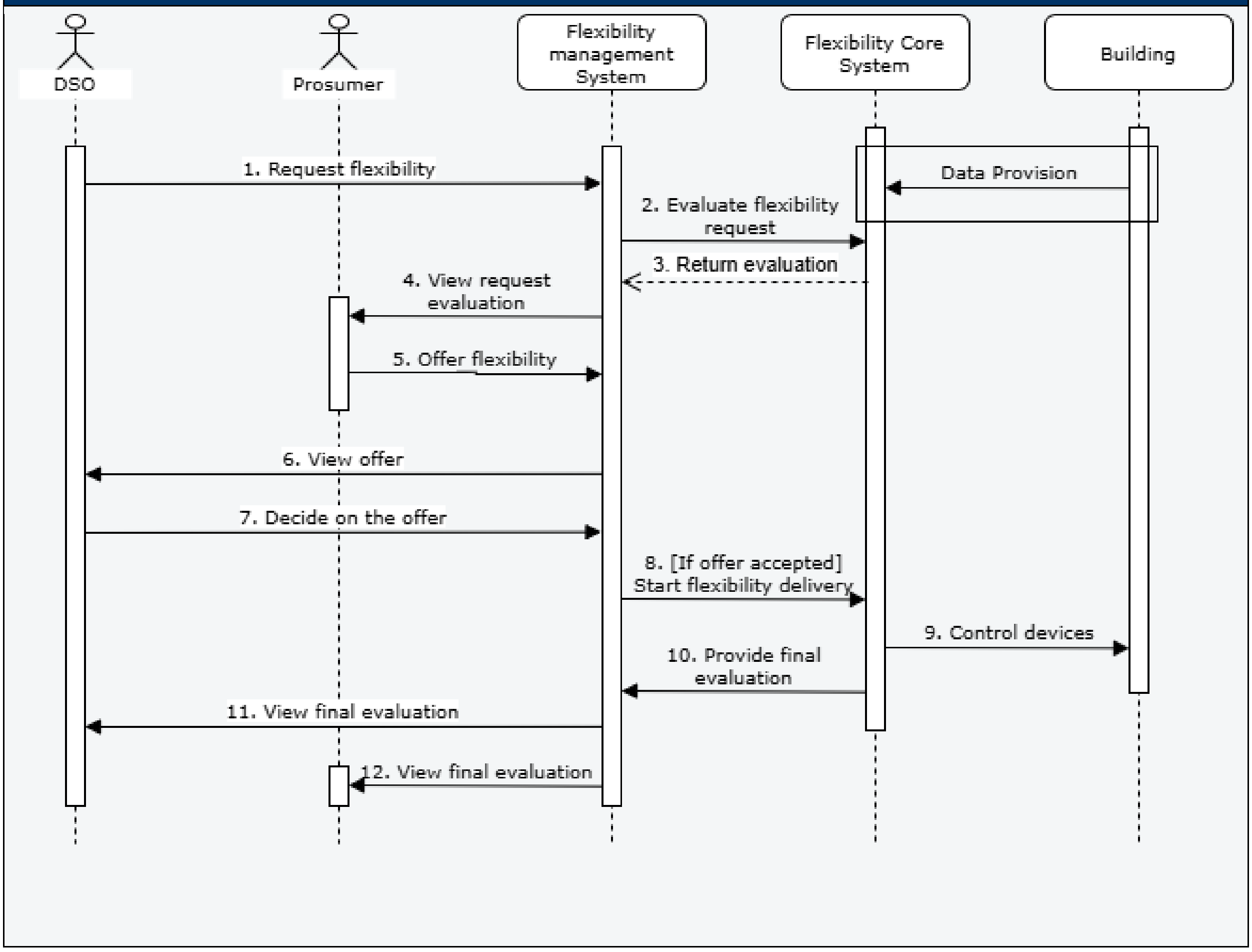
Scope and Objectives of Use Case	
Scope of the use case	The scope of this use case is analysis, optimization and real-time management of flexibility services.
Objectives of the use case	• Deploy energy flexibility of buildings and enhance the stability of the electricity grid in connection with DSOs and TSOs. • Develop a complete set of components for enabling flexibility services, including a decision support system for flexibility services market bidding. • Provide insights to the market participants.
Limitations & Assumptions	The procedure for providing flexibility services to DSO is established, and suitable supporting services are being provided at DSO.

Narrative of Use Case	
Short Description	In response to a flexibility request by a DSO or TSO, an analysis of energy flexibility potential of the available assets is made, followed by an optimization, which results in a selection of possible responses. The choice can be then made by a human operator or automatically. At implementation time (usually in 24 hours), the system takes care of adaptations that are necessary due to subsequent and real-time changes in the modelled environment.
Complete Description	In response to a flexibility request from a Distribution System Operator (DSO) or a Transmission System Operator (TSO), a comprehensive analysis is conducted to evaluate the energy flexibility potential of the available assets. This assessment considers various factors, including current energy consumption patterns, asset capabilities, and external conditions such as weather forecasts. The goal is to determine the extent to which energy demand or generation can be adjusted in a way that meets the operator's request. Following the analysis, an optimization process is performed to identify the most effective flexibility strategies. The optimization results in a selection of possible response options, each with different trade-offs and implications. Depending on the system design and operational preferences, the final choice of response can be made either by a human operator, who reviews the options and selects the most suitable one, or through an automated decision-making system that applies predefined algorithms and rules. At the implementation stage, which typically occurs within a 24-hour timeframe, the system ensures that necessary adaptations are made to account for subsequent changes in the modeled environment. These changes may arise from fluctuations in energy demand and supply or updated weather conditions.

	Real-time adjustments are carried out using advanced control mechanisms, predictive analytics, and communication with relevant grid and market actors to ensure that the flexibility response remains effective and aligned with operational goals.

Diagrams of the UC

Sequence diagram of the use case



Technical Details of the UC

Actors			
Actor Name	**Actor Type**	**Actor Description**	**Further information specific to this Use Case**
Prosumer	Stakeholder	The end user that consumes and produces electricity	In case of the Slovenian pilot, Petrol will have the role of a prosumer
DSO	Stakeholder	The end user of electricity flexibility services, Distribution System Operator	In case of the Slovenian pilot, Elektro Celje will have the role of a DSO
SEEDS Flexibility Services System (SEEDS FSS)	System	The system that will enable aggregation of prosumer's flexibility capabilities and their offering to DSO	The system for electricity flexibility that will be developed in SEEDS
SEEDS Flexibility UI	(Sub-)System	The User Interface of the SEEDS FSS	–
Flexibility Core System	(Sub-)System	The Core System of the SEEDS FSS	–
Building(s)	(Sub-)System	One or more buildings that are integrated in the SEEDS FSS	–

Step-by-step analysis of use case

Overview of scenarios

Scenario Conditions						
No	**Scenario title**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-Condition**
S01	Request Flexibility	DSO sends the prosumer request for electricity flexibility	DSO	DSO needs flexibility in their distribution system within the next day	DSO and prosumer are connected with the SEEDS FSS; SEEDS FSS is operational; DSO and prosumer have an active contract for flexibility services	None
S02	View Flexibility	Prosumer checks for flexibility requests and triggers their	Prosumer	Fixed time deadline (e.g., each day at 8h	Scenario S01 completed within a predefined time	None

Scenario Conditions						
No	**Scenario title**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-Condition**
	Request Evaluation	evaluation (according to criteria such as cost, price, risk, ...)		in the morning)	window (typically within this day)	
S03	Offer Flexibility	Based on the evaluation results from S02, prosumer's manager decides to make an offer or not	Prosumer	Fixed time deadline (e.g., each day at 11h in the morning)	Finished evaluation triggered in scenario S02	None
S04	View and Accept or Reject Flexibility Offer	The DSO's manager checks the prosumer's offer and decides to accept it or not	DSO	Fixed time deadline (e.g., each day at 12h)	Posted prosumer's offer from scenario S03	None
S05	Deliver Flexibility	If DSO accepts prosumer's offer, the offered flexibility is delivered	Prosumer	Fixed time trigger as specified in the prosumer's offer (and in line with DSO's request)	Accepted prosumer's offer by DSO	None
S06	View Flexibility Delivery Evaluation	Complete evaluation of the delivered flexibility is performed by the system (mostly for prosumer's information, DSO also performs a separate evaluation on their own)	DSO, Prosumer	Flexibility delivery from scenario S05 is completed	Flexibility delivery from scenario S05 is completed	None

Co-funded by the European Union

Steps per scenario

Scenario Name	S01 – "Request Flexibility"							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
St1	Request	Request for flexibility	DSO posts request for flexibility to the system	SEEDS FSS UI	DSO	SEEDS FSS	Parameters specifying flexibility request (time window, flexibility amount)	Established connection between DSO and SEEDS FSS

Scenario Name	S02 – "View Flexibility, Request Evaluation"							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
St1	Request	View request for flexibility	Prosumer views DSO's request for flexibility	SEEDS FSS UI	DSO	SEEDS FSS	Parameters specifying flexibility request (time window, flexibility amount)	Established connection between Prosumer and SEEDS FSS
St2	Request	Request evaluation	Prosumer requests evaluation of DSO's request for flexibility	SEEDS FSS UI	DSO	SEEDS FSS	Trigger flexibility request evaluation (Boolean)	Established connection between Prosumer and SEEDS FSS
St3	Response	Receive evaluation	Prosumer receives evaluation of DSO's request for flexibility	SEEDS FSS UI	SEEDS FSS	Prosumer	Parameters specifying one or more options for a flexibility offer (complete device schedules for each offer)	Established connection between Prosumer and SEEDS FSS

Co-funded by
the European Union

Scenario Name		S03 – "Offer Flexibility"						
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
St1	Request	Offer flexibility	Prosumer decides to offer (or not) one of the evaluated flexibility options	SEEDS FSS UI	Prosumer	SEEDS FSS	Confirmation for one or zero flexibility offer options	Established connection between Prosumer and SEEDS FSS

Scenario Name		S04 – "View and Accept or Reject Flexibility Offer"						
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
St1	Request	View flexibility offer	DSO views prosumer's flexibility offer	SEEDS FSS UI	Prosumer	DSO	Parameters specifying the flexibility offer (price, ...)	Established connection between DSO and SEEDS FSS
St2	Request	Accept or not the flexibility offer	DSO decides to accept (or not) the flexibility offer	SEEDS FSS UI	DSO	SEEDS FSS	Decision on flexibility offer acceptance (Boolean)	Established connection between DSO and SEEDS FSS

Scenario Name		S05 – "Deliver Flexibility"						
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
St1	Request	Deliver flexibility	System delivers flexibility to the grid	SEEDS FSS UI	SEEDS FSS	SEEDS FSS	None	Operational SEEDS FSS system

Co-funded by
the European Union

Scenario Name	S06 – "View Flexibility Delivery Evaluation"							
Step No.	**Event**	**Name of Process/ Activity**	**Description of Process/ Activity**	**Service**	**Information Producer (Actor)**	**Information Receiver (Actor)**	**Information exchanged (IDs)**	**Requirements, R-ID**
St1	Request	View flexibility delivery evaluation	DSO views flexibility delivery evaluation	SEEDS FSS UI	SEEDS FSS	DSO	Parameters of evaluation of the delivered flexibility (time profile)	Established connection between DSO and SEEDS FSS
St2	Request	View flexibility delivery evaluation	Prosumer views flexibility delivery evaluation	SEEDS FSS UI	SEEDS FSS	Prosumer	Parameters of evaluation of the delivered flexibility (time profile)	Established connection between Prosumer and SEEDS FSS

4. KPIS

4.1. KPIS RELATED TO ELECTRIFICATION SYSTEMS

4.1.1. Increase of RES power at demo site

PART A: KPI Profile				
KPI Name:	**Increase of RES power at demo site**	**Type:**	**CORE**	SUPPORTING
Description:	This KPI identifies the increase in renewable energy power after the installation of the innovative system on-site. It distinguishes between installed peak power capacity and actual energy generation, ensuring a more accurate representation of the system's impact.			
PART B: KPI Calculation				
Unit:	kWp, kWh	**Baseline Estimations Required:**	**YES**	NO
KPI Formula:	$RES\ Capacity\ increase\ [kWp] = RES\ Capacity\ after\ innovative\ system\ installation\ [kWp] - RES\ Capacity\ before\ the\ innovative\ system\ installation\ [kWp]$ Alternatively, $RES\ Energy\ increase\ [kWh] = RES\ Energy\ after\ innovative\ system\ installation\ [kWh] - RES\ Energy\ before\ the\ innovative\ system\ installation\ [kWh]$			
Recommended Data Sources:	Relevant data can be extracted from on-site monitoring systems installed at the demo-site			
Recommended time interval of KPI reporting:	Monthly; Annually	**Recommended time interval for data monitoring:**	Daily (for energy generation tracking), Monthly (for capacity evaluation)	

4.1.2. Renewable energy production

PART A: KPI Profile				
KPI Name:	**Renewable energy production**	**Type:**	**CORE**	SUPPORTING
Description:	Renewable energy is produced from unlimited natural resources and can be used for electricity generation, heating and cooling as well as transportation. This KPI quantifies the energy produced on-site after the implementation of the innovative RES system, covering both electrical and thermal outputs.			
PART B: KPI Calculation				
Unit:	kWh/year	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	*Electrical energy output* *Thermal energy output*			
Recommended Data Sources:	Relevant data can be collected from energy meters and sensors installed for both electrical and thermal energy monitoring on-site			
Recommended time interval of KPI reporting:	Monthly; Annually	**Recommended time interval for data monitoring:**	Daily; Monthly	

4.1.3. Energy demand reduction

PART A: KPI Profile				
KPI Name:	**Energy demand reduction**	**Type:**	**CORE**	SUPPORTING
Description:	The energy demand is the amount of energy required by the end users to meet their needs. This KPI quantifies the reduction in grid-based electrical energy demand reduction in the demo-site after the implementation of the innovative RES system.			
PART B: KPI Calculation				
Unit:	%	**Baseline Estimations Required:**	**YES**	NO
KPI Formula:	$Energy\ demand\ reduction\ [\%] = \left(\frac{Energy\ demand\ before\ [kWh] - Energy\ demand\ after\ [kWh]}{Energy\ demand\ before\ [kWh]}\right) x100$			
Recommended Data Sources:	Relevant data can be obtained from energy measurements on-site, energy simulations and database.			
Recommended time interval of KPI reporting:	Monthly; Annually	**Recommended time interval for data monitoring:**	Daily; Monthly	

Co-funded by the European Union

4.1.4. Increase of energy production from the innovative system compared to conventional RES systems

PART A: KPI Profile				
KPI Name:	**Increase of renewable energy production compared to conventional RES systems**	**Type:**	**CORE**	SUPPORTING
Description:	This KPI measures the percentage increase in energy production after the innovative RES system is implemented compared to the electrical energy produced by conventional RES systems. Conventional RES systems refer to typical renewable energy installations that lack the innovative features of the new system. The formula can be used for all types of energy (e.g., thermal, electrical, etc.) depending on the system being evaluated.			

PART B: KPI Calculation				
Unit:	%	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	$Increase\ of\ energy\ production = \left(\frac{Energy\ In\ [kWh] - Energy\ Con\ [kWh]}{Energy\ Con\ [kWh]}\right) x100$ *Energy In = Energy production from innovative RES system [kWh]* *Energy Con = Energy production from conventional RES system [kWh]*			
Recommended Data Sources:	Relevant data can be extracted from on-site measurements, simulations and database			
Recommended time interval of KPI reporting:	Monthly; Annually	**Recommended time interval for data monitoring:**	Daily; Monthly	

Co-funded by the European Union

4.1.5. GHG emissions reduction across the lifecycle

PART A: KPI Profile				
KPI Name:	**GHG emissions reduction across the lifecycle**	**Type:**	**CORE**	SUPPORTING
Description:	Integration of renewables is one of the pillars of the EU targets to reduce GHG emissions and reach climate neutrality by 2050. This KPI computes the difference between GHG emissions throughout the lifecycle of the innovative system and the GHG emissions of the conventional solutions.			
PART B: KPI Calculation				
Unit:	%	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	$GHG\ emission\ reduction\ [\%] = \left(\frac{GHG\ Conv\ [kgCO2/year] - GHG\ In}{GHG\ Conv \left[\frac{kgCO2}{year}\right]} \right) x100$ *GHG conv = GHG emissions of the conventional system [kgCO₂/year]* *GHG In = GHG emissions of the innovative system [kgCO₂/year]*$x100$			
Recommended Data Sources:	Relevant data can be extracted from simulations and database. Note: CO_2 emission factors should be referenced from recognized public sources (e.g., IPCC, European Environment Agency, or national inventories) to ensure accuracy and transparency.			
Recommended time interval of KPI reporting:	Once	**Recommended time interval for data monitoring:**	Once	

4.1.6. Carbon payback period

PART A: KPI Profile				
KPI Name:	Carbon payback period	**Type:**	**CORE**	SUPPORTING
Description:	This KPI describes the required time for the project's renewable energy systems to payback the CO2 emissions released during the manufacturing phase.			
PART B: KPI Calculation				
Unit:	years	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	$Carbon\ payback\ period\ [years] = \frac{Initial\ CO2\ emissions\ \ [kgCO2eq]}{Annual\ CO2\ emissions\ savings\ [kgCO2eq/year]}$			
Recommended Data Sources:	Initial CO2 emissions include the embodied emissions and the emissions from manufacturing process			
Recommended time interval of KPI reporting:	Once	**Recommended time interval for data monitoring:**	Once	

Co-funded by
the European Union

4.1.7. Recyclability of the system

PART A: KPI Profile				
KPI Name:	Recyclability of the system	**Type:**	**CORE**	SUPPORTING
Description:	This KPI quantifies the degree of recyclability of the developed system. The more recyclable is the system the higher impact on the environment it has.			
PART B: KPI Calculation				
Unit:	%	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	$Recyclability\ of\ the\ system\ [\%] = \left(\frac{Components\ with\ potential\ of\ recyclability\ [kg, m^3, etc.]}{Total\ amount\ of\ components\ [kg, m^3, etc.]}\right) x100$			
Recommended Data Sources:	The components that can be recycled are expected to be assessed based on the % of waste recycled.			
Recommended time interval of KPI reporting:	Once	**Recommended time interval for data monitoring:**	Once	

Co-funded by the European Union

4.2. KPIS RELATED TO AUTOMATION SYSTEMS AND PLATFORMS

4.2.1. Energy Efficiency Improvements

<table>
<tr><th colspan="6">PART A: KPI Profile</th></tr>
<tr><td>KPI Name:</td><td>Energy Efficiency Improvements</td><td>Type:</td><td colspan="2">CORE</td><td>SUPPORTING</td></tr>
<tr><td>Description:</td><td colspan="5">Tracks the reduction in energy use compared to baseline levels before the implementation of smart automation systems. This KPI demonstrates how efficiently the system uses energy after deployment while maintaining or improving performance across pilots. The comparison should ideally be made under similar operating conditions. Improvements contribute to cost savings, reduced environmental impact, and energy sustainability</td></tr>
<tr><th colspan="6">PART B: KPI Calculation</th></tr>
<tr><td>Unit:</td><td>%</td><td>Baseline Estimations Required:</td><td colspan="2">YES</td><td>NO</td></tr>
<tr><td>KPI Formula:</td><td colspan="5">$$EnergyEfficiencyImprovement(\%) = \frac{BaselineEnergyConsumption - ActualEnergyConsumption}{BaselineEnergyConsumption} \times 100$$</td></tr>
<tr><td>Recommended Data Sources:</td><td colspan="5">Relevant data can be obtained from on-site energy measurements, historical consumption records, energy simulations and database records.</td></tr>
<tr><td>Recommended time interval of KPI reporting:</td><td>Monthly; Annually</td><td>Recommended time interval for data monitoring:</td><td colspan="3">Daily; Monthly</td></tr>
</table>

4.2.2. Increased system flexibility for energy players

PART A: KPI Profile				
KPI Name:	Increased system flexibility for energy players	**Type:**	**CORE**	SUPPORTING
Description:	This KPI evaluates the increased flexibility of the energy system facilitated by the SEEDS project's advancements in smart building automation and renewable energy integration. It assesses the system's ability to adapt to demand fluctuations, integrate renewable energy sources (RES), reduce congestion, and maintain power balance in terms of load, cost, and energy efficiency. Flexibility is measured as the capacity to modulate power and optimize energy utilization across buildings and grids, emphasizing stability (voltage and frequency control) and demand-side participation.			
PART B: KPI Calculation				
Unit:	Percentage (%) or W/€ (alternatively)	**Baseline Estimations Required:**	**YES**	NO
KPI Formula:	$\Delta SF = \frac{SystemFlexibility - SystemFlexibilitybaseline}{Peak} \times 100$ • SF: Flexibility under SEEDS-enabled technologies (e.g., RES integration, automation systems) • SF Baseline: Baseline flexibility (before SEEDS project implementation). • Peak: Peak load capacity involved in demand-side management. (alternatively) It can also be expressed related to cost as: $SFAC = \frac{Systemflexibility}{Cost}$			
Recommended Data Sources:	Relevant data can be obtained from on-site energy management systems, demand response platforms, grid operator records, smart meters and database records.			
Recommended time interval of KPI reporting:	Monthly; Annually	**Recommended time interval for data monitoring:**	Daily; Monthly	

Co-funded by the European Union

4.2.3. Platform Downtime

PART A: KPI Profile				
KPI Name:	Platform Downtime	**Type:**	**CORE**	SUPPORTING
Description:	Platform downtime refers to the period when an ICT platform or automation system is unavailable, preventing it from fulfilling its core functions (data collection, control, monitoring, etc.). This KPI measures both unplanned downtime (e.g., power outages, server failures) and planned downtime (e.g., updates, system reboots) across all SEEDS platforms and systems. For SEEDS, minimizing downtime is essential to ensure seamless operation of the smart building systems and continuous data collection for real-time energy management. Monitoring downtime helps to ensure the stability and reliability of the system, which is critical for effective energy automation, grid integration, and renewable energy usage			
PART B: KPI Calculation				
Unit:	Percentage (%) or Time (hours)	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	$Downtime = \frac{TotalTimeofCIPunavailability}{TotaltimeofCIPoperation(hours \vee daysetc.)} \times 100$			
Recommended Data Sources:	Relevant data can be obtained from system logs, network monitoring tools, server uptime records, maintenance reports, and database records.			
Recommended time interval of KPI reporting:	Annually	**Recommended time interval for data monitoring:**	Annually	

Co-funded by the European Union

4.2.4. ICT Response Time

PART A: KPI Profile				
KPI Name:	ICT Response Time	**Type:**	**CORE**	SUPPORTING
Description:	Captures the speed of the ICT system's response to transactions and data exchanges. It reflects system efficiency and readiness, which is critical for real-time operations and data processing in automation systems.			
PART B: KPI Calculation				
Unit:	ms/byte; sec/byte, min/byte (depends on the system)	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	$$ICTresponsetime = \frac{Transactiontime}{payload}$$			
Recommended Data Sources:	Relevant data can be obtained from system logs, network performance monitoring tools, server response time records, and database transaction logs.			
Recommended time interval of KPI reporting:	Once	**Recommended time interval for data monitoring:**	Once	

4.2.5. Improved Interoperability

PART A: KPI Profile				
KPI Name:	Improved Interoperability	**Type:**	**CORE**	SUPPORTING
Description:	This KPI assesses the ability of systems to interact seamlessly, exchange data, and work collaboratively. This includes syntactic (communication) and semantic (understanding exchanged data) interoperability, as well as cross-domain interactions			
PART B: KPI Calculation				
Unit:	Number / Likert Scale (1–5)	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	Likert Scale assessment: 1: Not at all 2: Poor 3: Fair 4: Good 5: Excellent interoperability			
Recommended Data Sources:	Survey, interviews			
Recommended time interval of KPI reporting:	Annually	**Recommended time interval for data monitoring:**	Annually	

Co-funded by
the European Union

4.2.6. Quality of Open Data

PART A: KPI Profile				
KPI Name:	Quality of Open Data	**Type:**	**CORE**	SUPPORTING
Description:	This KPI measures the extent to which data in the SEEDS project adheres to DCAT (Data Catalog Vocabulary) standards for data that are shared openly. The DCAT standard facilitates interoperability and accessibility between different data catalogs, ensuring that data can be easily discovered, shared, and reused across systems. By adhering to DCAT, the quality of open data is improved, and data becomes more transparent, interoperable, and reusable. This is crucial for the SEEDS project as it ensures data is consistently structured and accessible for integration into various platforms, especially in the context of smart grids and energy management systems.			

PART B: KPI Calculation				
Unit:	%	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	$\text{Quality of Open Data} = \frac{Number\ of\ Datasets\ Adhering\ to\ DCAT}{\text{Total Number of Datasets}} \times 100$			
Recommended Data Sources:	Relevant data can be obtained from metadata repositories, data catalog validation tools, compliance reports, and database records.			
Recommended time interval of KPI reporting:	Once	**Recommended time interval for data monitoring:**	Once	

4.2.7. Cost Reduction from Flexibility

PART A: KPI Profile				
KPI Name:	Cost Reduction from Flexibility	**Type:**	**CORE**	SUPPORTING
Description:	This KPI measures the cost savings generated by increased flexibility in the energy system, facilitated by automation. It evaluates how the system adapts to demand fluctuations, integrates renewable energy, and reduces energy costs by shifting consumption to off-peak periods or optimizing energy sources			
PART B: KPI Calculation				
Unit:	Percentage (%) or € saved	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	$\text{Cost Reduction from Flexibility} = \frac{\text{Savings in Cost due to Flexibility} \text{Total Costs}}{\text{Total Cost}} \times 100$			
Recommended Data Sources:	Relevant data can be obtained from energy billing records, demand response platform reports, market price data, automation system logs, and database records.			
Recommended time interval of KPI reporting:	Monthly; Annually	**Recommended time interval for data monitoring:**	Daily; Monthly; Annually	

4.2.8. System Efficiency

PART A: KPI Profile				
KPI Name:	System Efficiency	**Type:**	**CORE**	SUPPORTING
Description:	This KPI measures how efficiently the automation system converts energy input into useful energy output. It tracks the system's ability to minimize energy waste and optimize energy use across smart grids, buildings, or other automated systems			
PART B: KPI Calculation				
Unit:	Percentage (%)	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	$$\text{System Efficiency} = \frac{\textbf{Energy Output}}{\textbf{Energy Input}} \times 100$$ ○ ***Energy Output**: The usable energy or optimized energy delivered by the system.* ○ ***Energy Input**: The total energy used by the system.*			
Recommended Data Sources:	Relevant data can be obtained from on-site energy meters, energy management platforms, performance monitoring tools, and database records.			
Recommended time interval of KPI reporting:	Once	**Recommended time interval for data monitoring:**	Once	

Co-funded by
the European Union

4.2.9. Automation System Reliability

PART A: KPI Profile				
KPI Name:	Automation System Reliability	**Type:**	**CORE**	SUPPORTING
Description:	This KPI measures the operational reliability of the automation system. It tracks the percentage of time the system is fully operational without failures or interruptions, ensuring smooth performance of critical energy management tasks			
PART B: KPI Calculation				
Unit:	Percentage (%)	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	$$\text{Reliability} = \frac{\text{Total Operational Time}}{\text{Total Time Available}} \times 100$$ ○ **Total Operational Time**: The time the system was operational without failure. ○ **Total Time Available**: The total time the system was intended to be operational.			
Recommended Data Sources:	Relevant data can be obtained from system logs, performance monitoring tools, uptime records, maintenance reports, and database records.			
Recommended time interval of KPI reporting:	Once	**Recommended time interval for data monitoring:**	Once	

4.2.10. Number of Connected Devices or Systems

PART A: KPI Profile				
KPI Name:	Number of Connected Devices or Systems	**Type:**	**CORE**	SUPPORTING
Description:	This KPI measures the percentage of devices or systems that are utilizing the connectors provided by the ICT platform. A higher value indicates greater interoperability, as it suggests a larger number of devices or systems are integrated with the platform			
PART B: KPI Calculation				
Unit:	Percentage(%)	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	$$\text{Connected Devices or Systems} = \frac{\text{Number of devices/systems utilizing the ICT platform}}{\text{Total number of devices/systems}} \times 100$$			
Recommended Data Sources:	Relevant data can be obtained from system integration logs, network monitoring tools, device management systems, and database records.			
Recommended time interval of KPI reporting:	Once	**Recommended time interval for data monitoring:**	Once	

Co-funded by the European Union

4.2.11. API Response Time

PART A: KPI Profile				
KPI Name:	API Response Time	**Type:**	**CORE**	SUPPORTING
Description:	This KPI measures the time it takes for the API to respond to client requests. A faster response time indicates better API performance, contributing to an improved user experience and efficient system operation.			
PART B: KPI Calculation				
Unit:	Milliseconds (ms)	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	API Response Time (ms)= *Time When Response is Received−Time When Request is Sent* ○ *Time When Request is Sent: The exact timestamp when the API call is initiated by the client.* ○ *Time When Response is Received: The exact timestamp when the client receives a response from the API.*			
Recommended Data Sources:	Relevant data can be obtained from API logs, server response time monitoring tools, network performance tracking systems, and database records.			
Recommended time interval of KPI reporting:	Once	**Recommended time interval for data monitoring:**	Once	

4.2.12. Semantic Accuracy

PART A: KPI Profile				
KPI Name:	Semantic Accuracy	**Type:**	**CORE**	SUPPORTING
Description:	This KPI measures the degree to which the semantic representations accurately reflect the actual data and relationships they are intended to model. Higher accuracy ensures better interoperability and usability across systems.			
PART B: KPI Calculation				
Unit:	Number / Likert Scale (1–5)	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	1: Not at all 2: Poor 3: Fair 4: Good 5: Excellent interoperability			
Recommended Data Sources:	Relevant data can be obtained from data validation reports, semantic consistency checks, interoperability testing results, and user feedback surveys.			
Recommended time interval of KPI reporting:	Once	**Recommended time interval for data monitoring:**	Once	

4.2.13. Scalability in Connected Devices

PART A: KPI Profile				
KPI Name:	Scalability in Connected Devices	**Type:**	**CORE**	SUPPORTING
Description:	This KPI measures the system's capacity to integrate and manage an increasing number of connected devices without performance degradation. A higher scalability score (in percentage) indicates that the system can handle more devices and scale effectively, while a lower score suggests that the system is nearing its maximum capacity.			
PART B: KPI Calculation				
Unit:	%	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	*Scalability Score* = $\frac{Current\ Devide\ Count}{System'sMaximum\ Capacity} \times 100$ • *Current Device Count: The number of devices currently connected to the system.* • *System's Maximum Capacity: The maximum number of devices the system is designed to handle without performance degradation.*			
Recommended Data Sources:	Relevant data can be obtained from system performance monitoring tools, device management logs, network load balancing reports, and database records.			
Recommended time interval of KPI reporting:	Once	**Recommended time interval for data monitoring:**	Once	

4.2.14. Task Completion Accuracy

PART A: KPI Profile				
KPI Name:	Task Completion Accuracy	**Type:**	**CORE**	SUPPORTING
Description:	Measures how accurately the ICT system completes assigned tasks without human intervention or error. A bigger number may indicate greater system reliability			
PART B: KPI Calculation				
Unit:	%	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	*Accuracy* = $\frac{\text{Correctly completed tasks}}{Total\ Assigned\ Tasks} \times 100$ • *Correctly Completed Tasks: The number of tasks that the ICT system has successfully completed without errors or the need for human intervention.* • *Total Assigned Tasks: The total number of tasks that the system was assigned to complete in a given period, regardless of whether they were completed correctly or not.*			
Recommended Data Sources:	Relevant data can be obtained from task management systems, system logs, performance monitoring tools, and database records.			
Recommended time interval of KPI reporting:	Annually	**Recommended time interval for data monitoring:**	Annually	

Co-funded by the European Union

4.2.15. User Satisfaction with Automation Systems

PART A: KPI Profile				
KPI Name:	User Satisfaction with Automation Systems	**Type:**	CORE	**SUPPORTING**
Description:	This KPI measures the satisfaction level of end-users interacting with automation systems. It evaluates several aspects of user experience, including ease of use, system reliability, and perceived value. The higher the score, the greater the user satisfaction with the system's functionality, efficiency, and the overall experience.			
PART B: KPI Calculation				
Unit:	Likert Scale (1–5)	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	*Likert Scale:* *1: Very dissatisfied* *2: Dissatisfied* *3: Neutral* *4: Satisfied* *5: Very satisfied*			
Recommended Data Sources:	Relevant data can be obtained from user surveys, feedback forms, customer support logs, and usability testing results.			
Recommended time interval of KPI reporting:	Annually	**Recommended time interval for data monitoring:**	Annually	

Co-funded by
the European Union

4.3. KPIS RELATED TO SMART BUILDING SERVICES

4.3.1. Total Operational Cost per m² per Year

PART A: KPI Profile				
KPI Name:	Total Operational Cost per m² per Year	**Type:**	**CORE**	SUPPORTING
Description:	Measures the yearly cost to operate the HVAC system and electrical appliances in a building. It is essential for assessing the financial efficiency of the building's operation.			
PART B: KPI Calculation				
Unit:	€/m²/year	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	$\text{Total Operational Cost} = \frac{\text{Sum of all operational costs for all HVAC equipment}}{\text{Total floor area of the building}}$			
Recommended Data Sources:	Relevant data can be obtained from energy bills, maintenance logs, equipment usage records, HVAC system monitoring tools, and building management system (BMS) reports.			
Recommended time interval of KPI reporting:	Annually	**Recommended time interval for data monitoring:**	Daily	

4.3.2. Annual CO2 Emissions

PART A: KPI Profile				
KPI Name:	Annual CO2 Emissions	**Type:**	**CORE**	SUPPORTING
Description:	Measures the total yearly CO2 emissions from the operation of the HVAC system. It helps evaluate the environmental impact of building operations.			
PART B: KPI Calculation				
Unit:	kg CO2/ m²/year	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	$\text{Total Annual CO2 Emissions per } m^2 = \frac{\text{Energy use } (kWh) * \text{CO2 emission factor } (kg\ CO2/kWh)}{\text{Total floor area of the building}}$			
Recommended Data Sources:	Relevant data can be obtained from energy consumption records, CO2 emission factor databases, HVAC system logs, and building management system (BMS) reports.			
Recommended time interval of KPI reporting:	Annually	**Recommended time interval for data monitoring:**	Daily	

4.3.3. Annual Primary Energy Use per m²

PART A: KPI Profile				
KPI Name:	Annual Primary Energy Use per m²	**Type:**	**CORE**	SUPPORTING
Description:	Measures the total primary energy use needed for heating and cooling. It reflects the building's energy efficiency			
PART B: KPI Calculation				
Unit:	kWh/m²/year	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	$\text{Annual Primary Energy Use per } m^2 = \frac{\text{Total energy used by HVAC}}{\text{Total floor area of the building}}$			
Recommended Data Sources:	Relevant data can be obtained from energy meters, HVAC system monitoring tools, energy management systems, and building management system (BMS) reports.			
Recommended time interval of KPI reporting:	Annually	**Recommended time interval for data monitoring:**	Continuous monitoring (15min), aggregated daily, monthly, yearly	

4.3.4. Annual Electricity Use per m²

PART A: KPI Profile				
KPI Name:	Annual Electricity Use per m²	**Type:**	**CORE**	SUPPORTING
Description:	Measures total electricity use of the building over a year, including all energy needs for heating and cooling, crucial for estimating operational costs and sustainability impact			
PART B: KPI Calculation				
Unit:	kWh/m²	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	$\text{Annual Electricity Use per m}^2 = \frac{\text{Total electricity used by HVAC}}{\text{Total floor area of the building}}$			
Recommended Data Sources:	Relevant data can be obtained from energy meters, electricity consumption records, HVAC system monitoring tools, and building management system (BMS) reports.			
Recommended time interval of KPI reporting:	Annually	**Recommended time interval for data monitoring:**	Continuous monitoring (15min), aggregated daily, monthly, yearly	

Co-funded by
the European Union

4.3.5. Peak Electricity Demand per m²

PART A: KPI Profile				
KPI Name:	Peak Electricity Demand per m²	**Type:**	**CORE**	SUPPORTING
Description:	Measures the maximum electricity use per unit area during the peak usage period. Important for evaluating the building's power capacity and load management			
PART B: KPI Calculation				
Unit:	kW/m²	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	$Peak\ Electricity\ Demand = \frac{Maximum\ instantaneous\ electricity\ use}{Total\ floor\ area\ of\ the\ building}$			
Recommended Data Sources:	Relevant data can be obtained from power meters, energy monitoring systems, building management system (BMS) reports, and load forecasting tools.			
Recommended time interval of KPI reporting:	Monthly; Annually	**Recommended time interval for data monitoring:**	Monthly	

4.3.6. Annual Heating Demand per m²

PART A: KPI Profile				
KPI Name:	Annual Heating Demand per m²	**Type:**	**CORE**	SUPPORTING
Description:	The total amount of thermal energy required by the building over a given period, essential for assessing energy consumption and operational costs.			
PART B: KPI Calculation				
Unit:	kWh/m²	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	$Annual\ Heating\ Demand\ per\ m2 = \frac{Total\ thermal\ energy\ supplied\ by\ the\ HVAC}{Total\ floor\ area\ of\ the\ building}$			
Recommended Data Sources:	Relevant data can be obtained from HVAC system logs, thermal energy meters, building management system (BMS) reports, and energy consumption records for heating.			
Recommended time interval of KPI reporting:	Annually	**Recommended time interval for data monitoring:**	Continuous monitoring (15min), aggregated daily, monthly, yearly	

Co-funded by
the European Union

4.3.7. Peak Heating Demand per m²

PART A: KPI Profile				
KPI Name:	Peak Heating Demand per m²	**Type:**	**CORE**	SUPPORTING
Description:	Represents the highest heating demand per unit area during the coldest period, critical for sizing HVAC systems			
PART B: KPI Calculation				
Unit:	kW/m²	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	$\text{Peak Heating Demand} = \frac{\textit{Maximum heating load}}{\textit{Total floor area of the building}}$			
Recommended Data Sources:	Relevant data can be obtained from HVAC system load measurements, temperature sensors, building management system (BMS) reports, and energy monitoring systems during the coldest periods.			
Recommended time interval of KPI reporting:	Monthly; Annually	**Recommended time interval for data monitoring:**	Continuous monitoring	

4.3.8. Annual Cooling Demand per m²

PART A: KPI Profile				
KPI Name:	Annual Cooling Demand per m²	**Type:**	**CORE**	SUPPORTING
Description:	The total amount of cooling energy required by the building over a given period, essential for assessing energy consumption and operational costs			
PART B: KPI Calculation				
Unit:	kWh/m²	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	$\textit{Annual Cooling Demand per m2} = \frac{\textit{Total thermal energy extracted by the HVAC}}{\textit{Total floor area of the building}}$			
Recommended Data Sources:	Relevant data can be obtained from HVAC system load measurements, temperature sensors, building management system (BMS) reports, and energy monitoring systems for cooling operations.			
Recommended time interval of KPI reporting:	Annually	**Recommended time interval for data monitoring:**	Continuous monitoring (15min), aggregated daily, monthly, yearly	

4.3.9. Peak Cooling Demand per m²

PART A: KPI Profile				
KPI Name:	Peak Cooling Demand per m²	**Type:**	**CORE**	SUPPORTING
Description:	Tracks the highest cooling demand per unit area during the hottest period, useful for evaluating cooling system performance and capacity			
PART B: KPI Calculation				
Unit:	kW/m²	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	$Peak\ Cooling\ Demand \frac{Maximum\ cooling\ load}{Total\ floor\ area\ of\ the\ building}$			
Recommended Data Sources:	Data for peak cooling demand can be sourced from temperature sensors, energy consumption meters, building management system (BMS) logs, and HVAC system performance reports.			
Recommended time interval of KPI reporting:	Monthly	**Recommended time interval for data monitoring:**	Continuous monitoring	

4.3.10. Yearly Thermal Discomfort

PART A: KPI Profile				
KPI Name:	Yearly Thermal Discomfort	**Type:**	**CORE**	SUPPORTING
Description:	Indicates the number of degree-hours during which the indoor temperature exceeds or falls below the comfort range. It is a measure of occupant comfort.			
PART B: KPI Calculation				
Unit:	Kh/year (degree-hours per year)	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	$\text{Thermal Discomfort} = \sum (\text{Hours outside comfort range} \times \lvert Temperature\ deviation\ from\ comfort\ zone \rvert$			
Recommended Data Sources:	Indoor temperature sensors, building management system (BMS) logs, weather data for outdoor temperatures, and occupant feedback (if applicable).			
Recommended time interval of KPI reporting:	Annually	**Recommended time interval for data monitoring:**	Kh/year (degree-hours per year)	

Co-funded by the European Union

4.3.11. Indoor Air Quality (CO_2 Concentration)

PART A: KPI Profile				
KPI Name:	Indoor Air Quality (CO_2 Concentration)	**Type:**	**CORE**	SUPPORTING
Description:	This KPI monitors the average concentration of CO_2 in indoor spaces, serving as an indicator of air quality and ventilation effectiveness. Elevated CO_2 levels can indicate poor ventilation, which may lead to discomfort, reduced productivity, or health concerns for occupants. By tracking CO_2 concentration, this KPI helps ensure that indoor environments are safe, comfortable, and well-ventilated			
PART B: KPI Calculation				
Unit:	ppm (parts per million)	**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	$\text{Indoor Air Quality } (\mathrm{CO_2}) = \frac{\sum CO_2 concentrations\ in\ each\ zone}{\text{number of zones}}$ • *CO_2 concentrations in each zone: The measured CO_2 concentration (in ppm) in each individual zone within the monitored area.* • *Number of zones: The total number of zones being monitored for CO_2 levels.*			
Recommended Data Sources:	CO_2 sensors installed in various zones within the building, building management system (BMS) data.			
Recommended time interval of KPI reporting:	Monthly; Annually	**Recommended time interval for data monitoring:**	Continuous monitoring	

Co-funded by the European Union

4.4. KPIS RELATED TO SMART GRID SERVICES

4.4.1. Delivered Flexibility

PART A: KPI Profile				
KPI Name:	Delivered Flexibility	**Type:**	**CORE**	SUPPORTING
Description:	Measures the amount of flexibility energy delivered during the demand-response/flexibility event; it can be positive or negative			
PART B: KPI Calculation				
Unit:	[kWh]	**Baseline Estimations Required:**	**YES**	NO
KPI Formula:	$$C = \int_{l_{DR},start}^{l_{DR},end} (P_{dr} - P_{ref})dt$$ • P_{ref} is the consumed power in the reference scenario [kW] • P_{dr} is the altered consumed power during the demand-response/flexibility event [kW]			
Recommended Data Sources:	Energy management systems (EMS), smart meters, demand-response systems, and grid integration data.			
Recommended time interval of KPI reporting:	Monthly; Annually	**Recommended time interval for data monitoring:**	Per event, Daily; Monthly; Annually	

4.4.2. Flexibility Factor

PART A: KPI Profile				
KPI Name:	Flexibility Factor	**Type:**	**CORE**	SUPPORTING
Description:	compares the amount of electricity consumed when the prices are high with the one when the prices are low			
PART B: KPI Calculation				
Unit:		**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	$$F_{flexibility} = \frac{\sum(E_{el}(t)c(t))_{low\_price} - \sum(E_{el}(t)c(t))_{high\_price}}{\sum(E_{el}(t)c(t))_{low\_price} + \sum(E_{el}(t)c(t))_{high\_price}}$$ • E_{el} is the electricity consumption at time t [kWh] • c is the electricity price at time t [any currency/kWh]			
Recommended Data Sources:	Energy consumption data (from smart meters or building management systems), electricity price data (from utility providers or dynamic pricing platforms), and demand-side management systems.			
Recommended time interval of KPI reporting:	Monthly	**Recommended time interval for data monitoring:**	over the entire heating season	

4.4.3. Flexibility Index

PART A: KPI Profile				
KPI Name:	Flexibility Index	**Type:**	**CORE**	SUPPORTING
Description:	compares the penalty of a reference case with the price-responsive controlled case			
PART B: KPI Calculation				
Unit:		**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	$FI = 1 - \frac{\sum penalty\ of\ price\ responsive\ case}{\sum penalty\ of\ base\ case} = 1 - \frac{\sum(E_{el}(t)c(t))_{flex}}{\sum(E_{el}(t)c(t))_{ref}}$ • E_{el} is the electricity consumption at time t [kWh] • c is the electricity price at time t [any currency/kWh]			
Recommended Data Sources:	Electricity consumption data (from smart meters or building management systems), electricity price data (from utility providers or dynamic pricing platforms), and demand-side management systems for both price-responsive and reference cases.			
Recommended time interval of KPI reporting:	Annually	**Recommended time interval for data monitoring:**	both short and long terms	

4.4.4. Shifted Flexible Load

PART A: KPI Profile				
KPI Name:	Shifted flexible load	**Type:**	**CORE**	SUPPORTING
Description:	shows the amount of shifted electricity of a price-responsive controlled case compared to a reference case for both downward and upward flexibilities			
PART B: KPI Calculation				
Unit:		**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	$S_{flex,downward} = \frac{\sum \max(E_{el,ref}(t) - E_{el,flex}(t),0)}{\sum E_{el,ref}(t)}$ $S_{flex,upward} = \frac{\sum \max(E_{el,flex}(t) - E_{el,ref}(t),0)}{\sum E_{el,ref}(t)}$ • $E_{el,ref}$ is the electricity consumption of reference case at time t [kWh] • $E_{el,flex}$ is the electricity consumption of price-responsive controlled case at time t [kWh]KP			
Recommended Data Sources:	Smart meter data or energy consumption data for both reference and price-responsive controlled cases. Data from demand-response systems or control mechanisms that manage the price-responsive adjustments.			
Recommended time interval of KPI reporting:	Annually; Monthly	**Recommended time interval for data monitoring:**	both short and long terms	

Co-funded by the European Union

4.4.5. Self-consumption rate

PART A: KPI Profile				
KPI Name:	Self-consumption rate	**Type:**	**CORE**	SUPPORTING
Description:	Shows the amount of directly used PV self generation in the building			
PART B: KPI Calculation				
Unit:		**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	when $E_{PV} \neq 0$, $$SCR = \sum \frac{min\ (E_{el}(t);\ E_{PV}(t))}{E_{PV}(t)}$$ • E_{el} is the electricity consumption at time t [kWh] • E_{PV} is the PV electricity production at time t [kWh]			
Recommended Data Sources:	Smart meter data for building electricity consumption. Data from the photovoltaic (PV) system monitoring, detailing energy production.			
Recommended time interval of KPI reporting:	Annually; Monthly	**Recommended time interval for data monitoring:**	short term	

4.4.6. Supply Cover Factor

PART A: KPI Profile				
KPI Name:	supply cover factor	**Type:**	**CORE**	SUPPORTING
Description:	the relation between the energy produced on-site and directly used and the total on-site produced energy			
PART B: KPI Calculation				
Unit:		**Baseline Estimations Required:**	YES	**NO**
KPI Formula:	when $P_{PV} \neq 0$, for all dt, $$\gamma_{supply} = \frac{\int \min\ (P_{PV}(t), P_{used}(t))dt}{\int P_{PV}(t)dt}$$ • P_{PV} is the PV electricity production during time interval dt [kW] • P_{used} is the power consumption during time interval dt [kW]			
Recommended Data Sources:	Power consumption data from building's electrical systems. Photovoltaic (PV) system monitoring data for energy production.			
Recommended time interval of KPI reporting:	Monthly; Annually	**Recommended time interval for data monitoring:**	short/long terms	

Co-funded by the European Union

4.4.7. Grid delivered factor

PART A: KPI Profile					
KPI Name:	Grid delivered factor	**Type:**		**CORE**	SUPPORTING
Description:	the relation between the electricity delivered from the grid and the total electricity used by the system over a time period				
PART B: KPI Calculation					
Unit:		**Baseline Estimations Required:**		YES	**NO**
KPI Formula:	when $P_{used} \neq 0$, for all dt, $$\gamma_{grid} = \frac{E_{del}}{E_{used}} = \frac{\int \max\left(P_{used}(t) - P_{PV}(t), 0\right)dt}{\int P_{used}(t)dt}$$ • E_{del} is the delivered electricity from the grid [kWh] • E_{used} is the total electricity used [kWh] • P_{PV} is the PV electricity production during time interval dt [kW] • P_{used} is the power consumption during time interval dt [kW]				
Recommended Data Sources:	Recommended data sources include energy consumption data, grid-delivered energy data, and photovoltaic system monitoring data.				
Recommended time interval of KPI reporting:	Annually	**Recommended time interval for data monitoring:**	short/long terms		

4.4.8. Additional energy consumed

PART A: KPI Profile					
KPI Name:	Additional energy consumed	**Type:**		**CORE**	SUPPORTING
Description:	the extra electricity import from the grid in a demand-response (DR) scenario with respect to the reference scenario				
PART B: KPI Calculation					
Unit:	[kWh]	**Baseline Estimations Required:**		YES	**NO**
KPI Formula:	$$\Delta E = E_{import}^{dr} - E_{import}^{ref}$$ • E_{import}^{dr} is the electricity imported from the grid in the DR scenario [kWh] • E_{import}^{ref} is the electricity imported from the grid in the reference scenario [kWh]				
Recommended Data Sources:	Recommended data sources include electricity import data from both demand-response (DR) and reference scenarios.				
Recommended time interval of KPI reporting:	Monthly, Annually	**Recommended time interval for data monitoring:**	short/long terms		

Co-funded by the European Union

4.4.9. Peak delivered

PART A: KPI Profile					
KPI Name:	Peak delivered	Type:		CORE	SUPPORTING
Description:	extreme power value of delivered electricity				
PART B: KPI Calculation					
Unit:	[kW]	Baseline Estimations Required:		YES	NO
KPI Formula:	$P_{del}^{max} = \max_{t}(P_{net}(t))$ • P_{net} is the net electricity ($P_{delivered} - P_{exported}$) [kW]				
Recommended Data Sources:	Recommended data sources include net electricity data (P_delivered) over time.				
Recommended time interval of KPI reporting:	Monthly	Recommended time interval for data monitoring:	long terms		

4.4.10. Peak exported

PART A: KPI Profile					
KPI Name:	Peak exported	Type:		CORE	SUPPORTING
Description:	extreme power value of exported electricity				
PART B: KPI Calculation					
Unit:	kW	Baseline Estimations Required:		YES	NO
KPI Formula:	$P_{exp}^{max} = -\min_{t}(P_{net}(t))$ P_{net} is the net electricity ($P_{delivered} - P_{exported}$) [kW]				
Recommended Data Sources:	Recommended data sources include net electricity data (P_exported) over time.				
Recommended time interval of KPI reporting:	Monthly	Recommended time interval for data monitoring:	long terms		

Co-funded by
the European Union

4.4.11. Energy cost reduction due to flexibility delivery

PART A: KPI Profile				
KPI Name:	Energy cost reduction due to flexibility delivery	**Type:**	**CORE**	SUPPORTING
Description:	measures energy cost reduction due to flexibility delivery			

PART B: KPI Calculation				
Unit:	€	**Baseline Estimations Required:**	YES	**NO**

KPI Formula:	$$CR = \sum(E_{el,flex}(t)c(t) - E_{el,flex}(t)b(t) + E_{el,flex}(t)p(t)) - \sum E_{el,ref}(t)c(t)$$ • $E_{el,ref}$ *is the electricity consumption in a reference scenario at time* t *[kWh]* • $E_{el,flex}$ *is the electricity consumption in a flexibility delivery scenario at time* t *[kWh]* • c *is the electricity price at time* t *[EUR/kWh]* • b *bonus for delivering flexibility at time* t *[EUR/kWh]* • p *penalty for not delivering enough flexibility at time* t *[EUR/kWh]* The formula above is just an example, because many cost computation schemas are possible, depending on specific contracts for flexibility services delivery.
Recommended Data Sources:	Recommended data sources include electricity consumption data, electricity prices, bonus and penalty values for flexibility delivery, and timestamps for flexibility service delivery events.

Recommended time interval of KPI reporting:	Monthly; Annually	**Recommended time interval for data monitoring:**	The complete time interval during which electricity consumption was altered in order to provide flexibility service (preparation, flexibility delivery and rebound periods); it can also include many flexibility delivery events over a longer time period, not just a single event.

Co-funded by the European Union

4.4.12. Peak demand reduction factor

<table>
<tr><th colspan="6">PART A: KPI Profile</th></tr>
<tr><td>KPI Name:</td><td>Peak demand factor</td><td>Type:</td><td colspan="2">CORE</td><td>SUPPORTING</td></tr>
<tr><td>Description:</td><td colspan="5">Compares the peak demand of reference and the price-responsive controlled case</td></tr>
<tr><th colspan="6">PART B: KPI Calculation</th></tr>
<tr><td>Unit:</td><td></td><td>Baseline Estimations Required:</td><td colspan="2">YES</td><td>NO</td></tr>
<tr><td>KPI Formula:</td><td colspan="5">$$PDF = \frac{(peak\ demand)_{flex} - (peak\ demand)_{ref}}{(peak\ demand)_{ref}}$$</td></tr>
<tr><td>Recommended Data Sources:</td><td colspan="5">Recommended data sources include peak demand data for both the reference and price-responsive controlled cases, along with timestamps for each demand period.</td></tr>
<tr><td>Recommended time interval of KPI reporting:</td><td>Monthly</td><td>Recommended time interval for data monitoring:</td><td colspan="3">short term</td></tr>
</table>

Co-funded by
the European Union

5. CONCLUSION

In conclusion, Deliverable D3.2 outlines the comprehensive methodology that will be used to evaluate the SEEDS project's effectiveness in decarbonizing buildings and enhancing energy efficiency. The development of KPIs serves as a crucial tool for measuring the project's progress in four key areas: electrification systems, automation systems, smart building services, and smart grid services. These KPIs are tailored to the specific needs of each pilot site, ensuring that the solutions implemented are scalable, replicable, and aligned with SEEDS' overarching objectives.

The collaborative approach, involving partners from various work packages, was essential for defining and finalizing the use cases and KPIs. The structured methodology, including the use of a modified IEC 62559 standard for use cases, ensures consistency and clarity in assessing the project's impact.

In total, 19 use cases were analyzed, including those for the Belgium pilot (4 use cases), Danish pilot (3 use cases), Greek pilot (6 use cases), Hungarian pilot (4 use case), and Slovenian pilot (2 use cases). The integration of these KPIs and use cases into the pilot sites' assessments will not only track the success of the SEEDS interventions but also allow for real-time adjustments and improvements, fostering innovation in building decarbonization.

ANNEXES

KPI Responsible: Responsible for managing general data collection. The KPI responsible and the data provider may be the same partner

Data Providers: Which partner will collect the data.

Monitoring Interval: At what time interval the data can be provided (e.g., hourly, daily, monthly, yearly).

ANNEX 1 BELGIUM PILOT KPIS

	KPI name	KPI responsible	Data providers	Monitoring interval
KPIs RELATED TO electrification systems				
1	**Increase of RES power at demo site**	maintenance company	Mintus/ Sweco	monthly
2	**Renewable energy production**	maintenance company	Mintus/ Builtwins	monthly
3	**Energy demand reduction** *only collective installations	Builtwins/ KUL	Mintus/ Builtwins	monthly
4	**Increase of energy production from the innovative system compared to conventional RES systems**	n/a	n/a	n/a
5	**GHG emissions reduction across the lifecycle**	n/a	n/a	n/a
6	**Carbon payback period**	n/a	n/a	n/a
7	**Recyclability of the system**	n/a	n/a	n/a
KPIs related to automation systems and platforms				
8	**Energy Efficiency Improvements**	Builtwins/ KUL	Builtwins/ Mintus	monthly
9	**Increased system flexibility for energy players**	n/a	n/a	n/a
10	**Platform Downtime**	Builtwins	Builtwins/ Mintus	yearly
11	**ICT Response Time**	n/a	n/a	n/a
12	**ICT Response Time**	n/a	n/a	n/a
13	**Quality of Open Data**	n/a	n/a	n/a
14	**Cost Reduction from Flexibility**	n/a	n/a	n/a
15	**System Efficiency**	Builtwins / KUL	Builtwins/ Mintus	daily
16	**Automation System Reliability**	Builtwins	Builtwins/ Mintus	monthly
17	**Number of Connected Devices or Systems**	n/a	Builtwins/ Mintus	n/a

Co-funded by the European Union

18	**API Response Time**	n/a	Builtwins	n/a
19	Semantic Accuracy	n/a	n/a	n/a
20	Scalability in Connected Devices	n/a	n/a	n/a
21	**Task Completion Accuracy**	Builtwins	Builtwins	monthly
22	User Satisfaction with Automation Systems	n/a	n/a	n/a
	KPIs related to smart building services			
23	**Total Operational Cost per m² per Year**	Builtwins	Builtwins	annual reporting
24	**Annual CO2 Emissions**	Builtwins	Builtwins	annual reporting
25	**Annual Primary Energy Use per m²**	Builtwins	Builtwins	annual reporting
26	**Annual Electricity Use per m²**	Builtwins	Builtwins	annual reporting
27	**Peak Electricity Demand per m²**	Builtwins	Builtwins	annual reporting
28	Annual Heating Demand per m²	n/a	n/a	n/a
29	Peak Heating Demand per m²	n/a	n/a	n/a
30	Annual Cooling Demand per m²	n/a	n/a	n/a
31	Peak Cooling Demand per m²	n/a	n/a	n/a
32	**Yearly Thermal Discomfort**	Builtwins	Builtwins	annual reporting
33	Indoor Air Quality (CO_2 Concentration) (excl. Greek pilot)	n/a	n/a	n/a
	KPIS RELATED TO SMART GRID SERVICES			
34	Delivered flexibility	n/a	n/a	n/a
35	Flexibility factor	n/a	n/a	n/a
36	Flexibility index	n/a	n/a	n/a
37	Shifted flexible load	n/a	n/a	n/a
38	Self consumption rate	n/a	n/a	n/a
39	Supply cover factor	n/a	n/a	n/a
40	Grid delivered factor	n/a	n/a	n/a
41	**Additional energy consumed**	KUL	KUL	annual reporting*
42	Peak delivered	n/a	n/a	n/a
43	Peak exported	n/a	n/a	n/a
44	**Energy cost reduction due to flexibility delivery**	KUL	KUL	annual reporting*
45	Peak demand factor	n/a	n/a	n/a

*based on simulations, no measurements in the pilot

Co-funded by
the European Union

ANNEX 2 DANISH PILOT KPIS

	KPI name	KPI responsible	Data providers	Monitoring interval
	KPIs RELATED TO electrification systems			
1	Increase of RES power at demo site	n/a	n/a	n/a
2	Renewable energy production	n/a	n/a	n/a
3	Energy demand reduction	n/a	n/a	n/a
4	Increase of energy production from the innovative system compared to conventional RES systems	n/a	n/a	n/a
5	GHG emissions reduction across the lifecycle	n/a	n/a	n/a
6	Carbon payback period	n/a	n/a	n/a
7	Recyclability of the system	n/a	n/a	n/a
	KPIs related to automation systems and platforms			
8	**Energy Efficiency Improvements**			hourly
9	**Increased system flexibility for energy players**	CDK	CDK	
10	Platform Downtime	n/a	n/a	n/a
11	ICT Response Time	n/a	n/a	n/a
12	ICT Response Time	n/a	n/a	n/a
13	Quality of Open Data	n/a	n/a	n/a
14	**Cost Reduction from Flexibility**	CDK	CDK	hourly
15	System Efficiency	n/a	n/a	n/a
16	Automation System Reliability	n/a	n/a	n/a
17	Number of Connected Devices or Systems	n/a	n/a	n/a
18	API Response Time	n/a	n/a	n/a
19	Semantic Accuracy	n/a	n/a	n/a
20	Scalability in Connected Devices	n/a	n/a	n/a
21	Task Completion Accuracy	n/a	n/a	n/a
22	User Satisfaction with Automation Systems	n/a	n/a	n/a
	KPIs related to smart building services			
23	Total Operational Cost per m² per Year	n/a	n/a	n/a
24	**Annual CO2 Emissions**	CDK	CDK/ENFOR	hourly
25	**Annual Primary Energy Use per m²**	CDK	CDK	hourly
26	**Annual Electricity Use per m²**	CDK	CDK	hourly
27	**Peak Electricity Demand per m²**	CDK	CDK	hourly

Co-funded by the European Union

28	**Annual Heating Demand per m²**	CDK	CDK	hourly
29	**Peak Heating Demand per m²**	CDK	CDK	hourly
30	**Annual Cooling Demand per m²**	CDK	CDK	hourly
31	**Peak Cooling Demand per m²**	CDK	CDK	hourly
32	**Yearly Thermal Discomfort**	CDK	CDK	hourly
33	**Indoor Air Quality (CO_2 Concentration) (excl. Greek pilot)**	n/a	n/a	n/a
KPIS RELATED TO SMART GRID SERVICES				
34	**Delivered flexibility**	CDK	CDK	hourly
35	**Flexibility factor**			
36	**Flexibility index**	CDK	CDK	hourly
37	**Shifted flexible load**	CDK	CDK	hourly
38	**Self consumption rate**	CDK	CDK/AI-ENERGY	hourly
39	**Supply cover factor**	CDK	CDK/AI-ENERGY	hourly
40	**Grid delivered factor**	CDK	CDK/AI-ENERGY	hourly
41	**Additional energy consumed**	n/a	n/a	n/a
42	**Peak delivered**	n/a	n/a	n/a
43	**Peak exported**	n/a	n/a	n/a
44	**Energy cost reduction due to flexibility delivery**	CDK	CDK/AI-ENERGY	hourly
45	**Peak demand factor**	n/a	n/a	n/a

ANNEX 3 GREEK PILOT KPIS

	KPI name	KPI responsible	Data providers	Monitoring interval
	KPIs RELATED TO electrification systems			
1	**Increase of RES power at demo site**	DUTH	DUTH	monthly
2	**Renewable energy production**	DUTH	DUTH	monthly
3	**Energy demand reduction**	DUTH	DUTH	monthly
4	**Increase of energy production from the innovative system compared to conventional RES systems**	DUTH	DUTH	monthly
5	**GHG emissions reduction across the lifecycle**	DUTH	DUTH	monthly
6	**Carbon payback period**	DUTH	DUTH	monthly
7	**Recyclability of the system**	DUTH	DUTH	once
	KPIs related to automation systems and platforms			
8	**Energy Efficiency Improvements**	DUTH	DUTH	monthly
9	**Increased system flexibility for energy players**	DUTH	DUTH	daily
10	**Platform Downtime**	CERTH	CERTH	daily
11	**ICT Response Time**	CERTH	CERTH	daily
12	**ICT Response Time**	CERTH	CERTH	daily
13	**Quality of Open Data**	CERTH	CERTH	monthly
14	**Cost Reduction from Flexibility**	CERTH	CERTH	monthly
15	**System Efficiency**	CERTH	CERTH	monthly
16	**Automation System Reliability**	CERTH	CERTH	monthly
17	**Number of Connected Devices or Systems**	CERTH	CERTH	daily
18	**API Response Time**	CERTH	CERTH	daily
19	**Semantic Accuracy**	CERTH	CERTH	daily
20	**Scalability in Connected Devices**	CERTH	DUTH	monthly
21	**Task Completion Accuracy**	DUTH	DUTH	monthly
22	**User Satisfaction with Automation Systems**	DUTH	DUTH	monthly
	KPIs related to smart building services			
23	**Total Operational Cost per m² per Year**	DUTH	DUTH	yearly
24	**Annual CO2 Emissions**	DUTH	DUTH	yearly
25	**Annual Primary Energy Use per m²**	DUTH	DUTH	yearly

Co-funded by the European Union

26	**Annual Electricity Use per m²**	DUTH	DUTH	yearly
27	**Peak Electricity Demand per m²**	DUTH	DUTH	yearly
28	**Annual Heating Demand per m²**	DUTH	DUTH	yearly
29	**Peak Heating Demand per m²**	DUTH	DUTH	yearly
30	**Annual Cooling Demand per m²**	DUTH	DUTH	yearly
31	**Peak Cooling Demand per m²**	DUTH	DUTH	yearly
32	**Yearly Thermal Discomfort**	DUTH	DUTH	yearly
33	**Indoor Air Quality (CO_2 Concentration) (excl. Greek pilot)**	DUTH	DUTH	yearly
KPIS RELATED TO SMART GRID SERVICES				
34	**Delivered flexibility**	CERTH	DUTH	
35	**Flexibility factor**	CERTH	DUTH	
36	**Flexibility index**	CERTH	DUTH	
37	**Shifted flexible load**	CERTH	DUTH	
38	**Self consumption rate**	CERTH	DUTH	daily
39	**Supply cover factor**	CERTH	DUTH	daily
40	**Grid delivered factor**	CERTH	DUTH	daily
41	**Additional energy consumed**	CERTH	DUTH	daily
42	**Peak delivered**	CERTH	DUTH	daily
43	**Peak exported**	CERTH	DUTH	daily
44	**Energy cost reduction due to flexibility delivery**	CERTH	DUTH	daily
45	**Peak demand factor**	CERTH	DUTH	daily

Co-funded by
the European Union

ANNEX 4 HUNGARIAN PILOT KPIS

	KPI name	KPI responsible	Data providers	Monitoring interval
	KPIs RELATED TO electrification systems			
1	**Increase of RES power at demo site**	HORBER	HORBER	yearly
2	**Renewable energy production**	HORBER	HORBER	yearly
3	**Energy demand reduction**	FairC	FairC	yearly
4	**Increase of energy production from the innovative system compared to conventional RES systems**	HORBER	HORBER	yearly
5	**GHG emissions reduction across the lifecycle**	ÉMI	ÉMI	once
6	**Carbon payback period**	ÉMI	ÉMI	yearly
7	**Recyclability of the system**	ÉMI	ÉMI	once
	KPIs related to automation systems and platforms			
8	**Energy Efficiency Improvements**	Profigram	Profigram	yearly
9	**Increased system flexibility for energy players**	Profigram	Profigram	yearly
10	**Platform Downtime**	Profigram	Profigram	yearly
11	**ICT Response Time**	Profigram	Profigram	yearly
12	**ICT Response Time**	Profigram	Profigram	yearly
13	**Quality of Open Data**	Profigram	Profigram	yearly
14	**Cost Reduction from Flexibility**	Profigram	Profigram	yearly
15	**System Efficiency**	Profigram	Profigram	yearly
16	**Automation System Reliability**	Profigram	Profigram	yearly
17	**Number of Connected Devices or Systems**	FairC	FairC	yearly
18	**API Response Time**	Profigram	Profigram	once
19	**Semantic Accuracy**	Profigram	Profigram	once
20	**Scalability in Connected Devices**	Profigram	Profigram	yearly
21	**Task Completion Accuracy**	Profigram	Profigram	yearly
22	**User Satisfaction with Automation Systems**	Profigram	Profigram	yearly
	KPIs related to smart building services			
23	**Total Operational Cost per m² per Year**	FairC	BP16	yearly
24	**Annual CO2 Emissions**	FairC	BP16	yearly
25	**Annual Primary Energy Use per m²**	FairC	BP16	yearly
26	**Annual Electricity Use per m²**	FairC	BP16	yearly
27	**Peak Electricity Demand per m²**	FairC	BP16	yearly

Co-funded by
the European Union

28	**Annual Heating Demand per m²**	FairC	BP16	yearly
29	**Peak Heating Demand per m²**	FairC	BP16	yearly
30	**Annual Cooling Demand per m²**	FairC	BP16	yearly
31	**Peak Cooling Demand per m²**	FairC	BP16	yearly
32	**Yearly Thermal Discomfort**	ÉMI	ÉMI	yearly
33	**Indoor Air Quality (CO_2 Concentration) (excl. Greek pilot)**	ÉMI	ÉMI	yearly
	KPIS RELATED TO SMART GRID SERVICES			
34	**Delivered flexibility**	Profigram	Profigram	yearly
35	**Flexibility factor**	Profigram	Profigram	yearly
36	**Flexibility index**	Profigram	Profigram	yearly
37	**Shifted flexible load**	Profigram	Profigram	yearly
38	**Self consumption rate**	Profigram	Profigram	yearly
39	**Supply cover factor**	Profigram	Profigram	yearly
40	**Grid delivered factor**	Profigram	Profigram	yearly
41	**Additional energy consumed**	Profigram	Profigram	yearly
42	**Peak delivered**	Profigram	Profigram	yearly
43	**Peak exported**	Profigram	Profigram	yearly
44	**Energy cost reduction due to flexibility delivery**	Profigram	Profigram	yearly
45	**Peak demand factor**	Profigram	Profigram	yearly

Co-funded by
the European Union

ANNEX 5 SLOVENIAN PILOT KPIS

	KPI name	KPI responsible	Data providers	Monitoring interval
	KPIs RELATED TO electrification systems			
1	Increase of RES power at demo site	n/a	n/a	n/a
2	Renewable energy production	n/a	n/a	n/a
3	Energy demand reduction	n/a	n/a	n/a
4	Increase of energy production from the innovative system compared to conventional RES systems	n/a	n/a	n/a
5	GHG emissions reduction across the lifecycle	n/a	n/a	n/a
6	Carbon payback period	n/a	n/a	n/a
7	Recyclability of the system	n/a	n/a	n/a
	KPIs related to automation systems and platforms			
8	Energy Efficiency Improvements	n/a	n/a	n/a
9	Increased system flexibility for energy players	n/a	n/a	n/a
10	**Platform Downtime**	JSI	PETROL	yearly
11	ICT Response Time	n/a	n/a	n/a
12	ICT Response Time	n/a	n/a	n/a
13	Quality of Open Data	n/a	n/a	n/a
14	Cost Reduction from Flexibility	n/a	n/a	n/a
15	System Efficiency	n/a	n/a	n/a
16	**Automation System Reliability**	JSI	PETROL	yearly
17	**Number of Connected Devices or Systems**	JSI	PETROL	yearly
18	**API Response Time**	JSI	PETROL	yearly
19	Semantic Accuracy	n/a	n/a	n/a
20	Scalability in Connected Devices	n/a	n/a	n/a
21	Task Completion Accuracy	n/a	n/a	n/a
22	User Satisfaction with Automation Systems	n/a	n/a	n/a
	KPIs related to smart building services			
23	Total Operational Cost per m² per Year	n/a	n/a	n/a
24	**Annual CO2 Emissions**	JSI	PETROL	yearly
25	**Annual Primary Energy Use per m²**	JSI	PETROL	yearly
26	**Annual Electricity Use per m²**	JSI	PETROL	yearly
27	Peak Electricity Demand per m²	n/a	n/a	n/a

28	Annual Heating Demand per m²	n/a	n/a	n/a
29	Peak Heating Demand per m²	n/a	n/a	n/a
30	Annual Cooling Demand per m²	n/a	n/a	n/a
31	Peak Cooling Demand per m²	n/a	n/a	n/a
32	Yearly Thermal Discomfort	n/a	n/a	n/a
33	Indoor Air Quality (CO_2 Concentration) (excl. Greek pilot)	n/a	n/a	n/a
KPIS RELATED TO SMART GRID SERVICES				
34	**Delivered flexibility**	JSI	PETROL	per event, daily
35	**Flexibility factor**	JSI	PETROL	daily
36	**Flexibility index**	JSI	PETROL	daily
37	**Shifted flexible load**	JSI	PETROL	per event, daily
38	**Self consumption rate**	JSI	PETROL	daily
39	**Supply cover factor**	JSI	PETROL	daily
40	**Grid delivered factor**	JSI	PETROL	daily
41	**Additional energy consumed**	JSI	PETROL	per event, daily
42	**Peak delivered**	JSI	PETROL	daily
43	**Peak exported**	JSI	PETROL	daily
44	**Energy cost reduction due to flexibility delivery**	JSI	PETROL	per event, daily
45	**Peak demand factor**	JSI	PETROL	per event, daily

Co-funded by the European Union

ANNEX 6 USE CASE TEMPLATE

Description of the Use Case

Use case Identification		
ID	**Title**	**Domain**
	Provide a clear and concise title for the use case that summarizes the main focus or objective.	Identify the primary domain or sector the use case falls under (e.g., Energy Efficiency, DER).

Version Management			
Version No	**Date**	**Name of authors**	**Changes**

Scope and Objectives of Use Case	
Scope of the use case	Describe the overall scope, including the boundaries, the main activities involved, and the key aspects the use case will address.
Objectives of the use case	List the specific goals the use case aims to achieve. These should be clear, measurable, and directly related to the scope of the use case.
Limitations & Assumptions	Identify any constraints, assumptions, or conditions that may impact the use case. (e.g regulatory, political)

Narrative of Use Case	
Short Description	Provide a brief explanation of the use case. The purpose is to create a concise text that summarizes the UC. (no more than 10 lines)
Complete Description	Offer a detailed description, including technical aspects, methodology, and any relevant background information. This section should give a comprehensive overview of how the use case will be implemented. The description should include motives and intents from a variety of actors. The text should include a step-by-step explanation of the service from start to finish. The story should include details such as when, why, with what expectation, and under what conditions.

Classification Information

Pilot Involved	Identify the primary organization or partner leading the use case
Relation to Other Use Cases	Provide if this UC is related to other UC
Related Innovative SEEDS solutions	List the specific SEEDS innovations and solutions that are relevant to the use case. Describe how they will be utilized or integrated.
Assets of the UC	Provide a list of assets which are needed specifically for this use case. (e.g HP, VRV, Chiller..)

Diagrams of the UC

Sequence diagram of the use case

Technical Details of the UC

Specify the actors which are involved in the use case. They can include roles, people, systems, devices, etc. (Actor Type: Can be a Role (a DSO, a Balance Responsible Party, an Aggregator…), a Person (a Distribution Management System Operator), a System (a Weather Forecast System, a Demand Response Management System, a Building Management System…), a Device (a charging spot), or an Application.)

A short description of the actors along with any further information should be included.

Actors			
Actor Name	**Actor Type**	**Actor Description**	**Further information specific to this Use Case**

Step-by-step analysis of use case

Overview of scenarios

In the next table, provide scenarios associated with the use cases described above.

- **No.**: The scenarios are sequentially numbered.
- **Scenario Name and description**: Describes the scenario and is used as identifier.
- **Primary Actor**: Describes which actor(s) trigger(s) this scenario.
- **Triggering Event**: Describes which event(s) trigger(s) this scenario.
- **Pre-Condition:** Describes which condition(s) should have been met before this scenario happens.
- **Post-Condition**: Describes which condition(s) should prevail after this scenario happens. The post conditions may also define “success” or “failure” conditions for each use case.

Scenario Conditions						
No	**Scenario title**	**Scenario description**	**Primary actor**	**Triggering event**	**Pre-condition**	**Post-Condition**
e.g S01	e.g Registration and Prequalification	DSO sends the prosumer an offer to use their PV inverter to control the voltage in the network	DSO, RP	DSO wants to use PV inverters installed at the prosumers site to do voltage control	The secondary substation to which prosumers are connected has been modernized to the level of a Flexstation	PV inverter connected with FS

Steps per scenario

Scenario Name:	**Registration and Prequalification**							
Step No.	Event	Name of Process/ Activity	Description of Process/ Activity	Service	Information Producer (Actor)	Information Receiver (Actor)	Informatio n exchanged (IDs)	Requirements, R-ID
e.g 1.1		e.g Offer of cooperatio n	DSO sends offers to prosumers to use a PV inverter to control the voltage in the grid	send	DSO	RP	Name of informatio n e.g Info1	

Co-funded by
the European Union

SEEDS

https://project-seeds.eu/

project-seeds

@EU_SEEDS