D8.4 SYNERGY Evaluation Framework and Respective Validation Scenarios

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Big Energy Data Value Creation within SYNergetic enERGY-as-a-service Applications through trusted multi party data sharing over an AI big data analytics marketplace

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Abbreviations and Acronyms

Acronym	Description
AI	Artificial Intelligence
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BaU	Business as Usual
BS	Business Scenarios
CA	City Authorities
CBA	Cost Benefit Analysis
DoA	Description of Action
DSO	Distribution System Operator
ECMs	Energy Conservation Measures
EEGI	European Electricity Grid Initiative
ESCO	Energy Service Companies
EPC	Engineering, Procurement and Construction
FEMP	Federal Energy Management Program
IPMVP	International Performance Measurement and Verification Protocol
JRC	Joint Research Centre
KPI	Key Performance Indicators
LCOE	Levelized cost of energy
MAPE	Mean Absolute Percentage Error
O&M	Operational and Maintenance
PMV	Performance Measurement and Verification
R&I	Research and Innovation
Re	Retailers
SRI	Quality System Registrat
TSO	Transmission System Operator
VSs	Validation Scenarios

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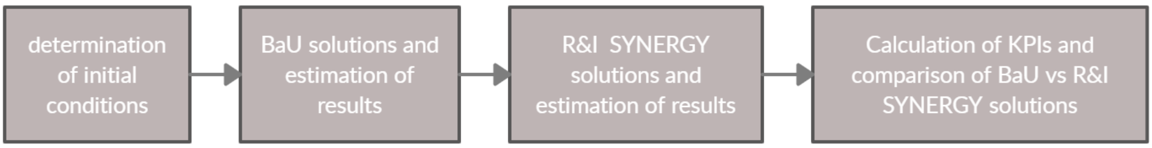
Executive summary

This document defines the framework for technical validation and evaluation of the SYNERGY ecosystem during the demonstration activities. Such demonstration activities help SYNERGY partners, acting as market stakeholders, to test the suitability of the proposed solutions in dealing with current, or foreseen, challenges and collect the appropriate data for evaluating the respective business models.

Existing approaches already being developed in other EU projects and in the international context have been considered for the definition of the methodology. Thus, a literature research work has been carried out and is presented in the first section of this document. Special attention has been given to the International Performance Measurement and Verification Protocol (IPMVP) and Federal Energy Management Programme (FEMP) protocols, the most used at international level for Measurement and Verification (M&V) projects and to previous EU projects.

Furthermore, we have defined a list of KPIs (Key Performance Indicators) which allows us to track the evaluation progress more effectively and strengthen the exploitation capabilities and market impact of the projects' outcomes. These KPIs, depending on their context can be grouped into energy, economic and environmental, and presented in ANNEX I, 'SYNERGY KPIs'. A total number of **54 KPIs** were identified. 43 KPIs fall into in the energy impact category, 9 fall into the economic and finally 2 fall into the environmental category.

The EEGI framework has been adopted, which proposes to compare the benefits of applying Research and Innovation (R&I solutions) with the expected benefits of applying Business as Usual (BaU) solutions:



On top of that, considering the data orientation of the project and the functional capabilities of the SYNERGY Big Data Platform, within which stakeholders can upload, exchange and retrieve energy data through the SYNERGY marketplace, it was decided that it is also important to evaluate the technical data-related aspects as well. Therefore, apart from SYNERGY KPIs, a list of Technical KPIs has also been defined introducing a set of Quantitative Technical Evaluation KPIs, Data Asset Quality Evaluation KPIs and User Experience/Acceptance Evaluation KPIs.

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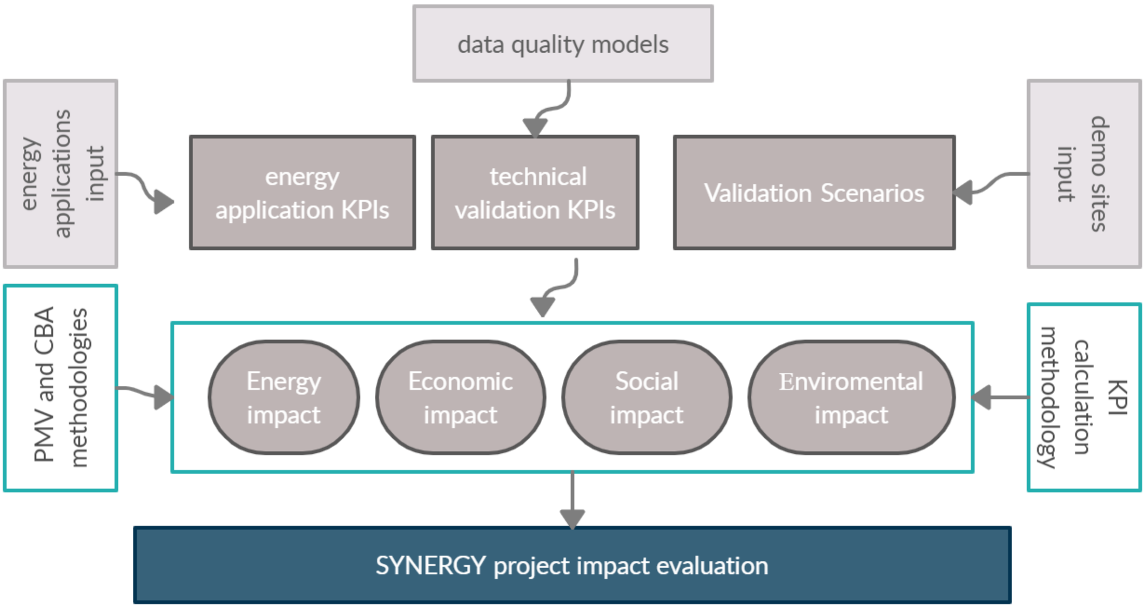
Another significant component of the SYNERGY Evaluation Framework is the consolidation of validation scenarios per demo case, complementing the demo cases defined within the DoA. Each validation scenario involves a distinct set of use cases, as they have been defined within D2.2, a distinct set of energy applications relevant to the demo cases, as they have been developed within the technical work packages WP5-WP6-WP7 and hereinafter a descriptive narrative of the workflow, data exchange, triggering events, interactions between stakeholders as they interweave within each demo case.

All the above - mentioned aspects are summarized in the flowchart below, where all the considered aspects to facilitate the SYNERGY project impact evaluation have been captured:



1 Introduction

1.1 Purpose of the document

The objective of this document, which is the main outcome of the T8.3 on “Detailed pilot evaluation, impact assessment and cost-benefit analysis framework”, is to define a global evaluation framework for the SYNERGY validation activities to be adopted by the SYNERGY project for verifying the innovative energy service applications and the SYNERGY Big Data Platform.

At first, this deliverable aims at identifying the Key Performance Indicators (KPIs) which will be used to support the monitoring process of Research and Innovation (R&I) activities, assess of the impacts of the proposed activities and evaluate the overall contribution of the SYNERGY framework. These KPIs shall measure the impact of the new solutions and monitor their performance. In addition, KPIs will be used to compare the various demonstration activities, and support the SYNERGY stakeholders to explore the different business cases that could originate from their participation in SYNERGY and adopt the SYNERGY key outputs and relevant energy applications into their everyday operations, following the validation activities of the project, at the end of the project. As such, deliverable D8.4, has defined a list of 54 KPIs which have been explicitly described and connected with the SYNERGY use cases, demo cases and energy applications (see Annex I). These KPIs have been for the most part, identified from the energy application developers, who anticipate the key outputs from the algorithms and analytics development. Thereinafter, the KPIs have been cross checked and acknowledged by demo partners, who will be utilizing the functionalities offered by the platform and the energy applications and validate them through the demo cases.

Except for the SYNERGY KPIs, given the data orientation of the SYNERGY project, where data belonging to different stakeholders are brought together via the SYNERGY Big Data Platform, it was deemed significant to also define Technical Validation KPIs, capturing data quality and data availability issues. Therefore , a set of Quantitative Technical Evaluation KPIs, Data Asset Quality Evaluation KPIs and User Experience/Acceptance Evaluation KPIs have been extracted from the relevant literature to allow evaluation of the project within this data aspect.

Furthermore, SYNERGY tools and solutions will be deployed in the different pilot sites through a set of demo cases. Therefore, a set of validation scenarios has been consolidated for the defined demo cases.

Actually, each Validation Scenario aims at demonstrating a particular combination of tools, or different approaches in dealing with the challenge at hand, different ways in motivating subjects’ participation

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amongst others. Each validation scenario involves a distinct set of use cases, as they have been defined within D2.2, a distinct set of energy applications relevant to the demo cases, as they have been developed within the technical work packages WP5-WP6-WP7 and hereinafter a descriptive narrative of the workflow, data exchange, triggering events, interactions between stakeholders as they interweave within each demo case.

This deliverable opens the path towards a Holistic Performance Evaluation, Impact Assessment and Cost-Benefit Analysis, which will be performed within the deliverable D8.5; 'SYNERGY Holistic Performance Evaluation, Impact Assessment and Cost-Benefit Analysis v1', to be published during M33 of the project, following the end of the first demo run and will be further elaborated and improved, with deliverable D8.6, 'SYNERGY Holistic Performance Evaluation, Impact Assessment and Cost-Benefit Analysis v2' , following the end of the second demo run on M42 of the project.

1.2 Scope of the document

Deliverable D8.4 'SYNERGY Evaluation Framework and Respective Validation Scenarios' aims to set the ground for the impact assessment activities of the SYNERGY project. As such, it will provide the necessary methodological pathway to enable the holistic evaluation and impact assessment of the project, following the pilot roll-out phase.

One of the objectives of this report is to provide the technical WPs, the demo cases and the project globally, with technical, energy, economic, environmental and social KPIs in order to quantify and evaluate the impact of the new solutions in the demonstration sites. Hence, it includes including the definition of the Key Performance Indicators as well as the first steps of the Cost Benefit Analysis (CBA), through the appropriate formulation of the KPIs.

Additionally, the evaluation framework has been further synthesized via the consolidation of respective validation scenarios as they are perceived from the demo case leaders. The validation scenarios contain the resulting interweave between, use cases, energy service applications, data analytics, stakeholders and the SYNERGY platform, setting the ground for properly evaluating SYNERGY and assess the value that different tools bring to the project.

1.3 SYNERGY Evaluation Framework Methodology

In SYNERGY, a solid methodological approach for the Evaluation Framework has been devised to ensure that the deriving evaluation approach builds on state-of-the art, and also upon other

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methodologies verified in EU projects and the literature to enable a holistic assessment of the project impact.

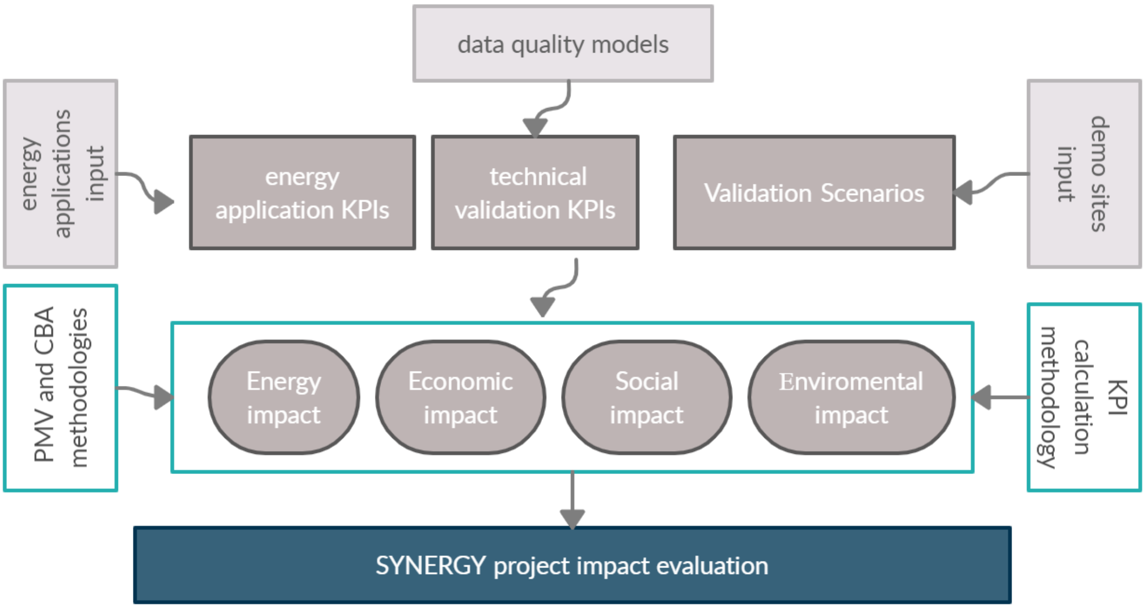

Figure 1: SYNERGY Evaluation Framework

As depicted in Figure 1, the project impact evaluation is materialized via the below axes:

- **PMV and CBA methodologies:** Combining well known evaluation tools such as Cost Benefit Analysis (CBA) and Performance Measurement and Verification (PMV) protocols. Regarding CBA, the methodology shall provide the framework to identify and quantify costs and benefits of SYNERGY research and innovation solutions when compared to business-as-usual scenarios, which express the situation of the grid ecosystem in the absence of the tools and technology considered in the context of the SYNERGY project. The BaU state is used as a comparison benchmark for the state of the grid after the implementation of the SYNERGY project. The comparison between the two states reflects the added value provided by the functionalities of the involved tools and the SYNERGY platform. Regarding PMV methodologies, they shall be referenced on the applications which deal with energy performance and energy related measurements to perform accurate baselining and normalize it against energy uses and climatic conditions
- **KPIs:** The proposed evaluation framework utilizes well-defined and measurable KPIs that will be monitored and assessed in different phases during the development of the project. The KPIs shall measure and verify the improvements on a variety of aspects achieved due to SYNERGY innovative energy services and applications. The KPIs have been defined taking into

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consideration KPIs found in other EU similar projects, reflecting applications objectives and outcomes and SYNERGY targeted impact assessment, regarding energy, economic and environmental goals. In addition, a list of technical KPIs aiming to quantify data-related aspects of the project has been assembled.

- **Validation Scenarios** have been consolidated from the demo partners of the project, bringing together energy services and applications, demo sites, use cases, demo cases and all involved stakeholders. They facilitate building the narrative of the sequences and workflows on how different software components, applications will interact and will be involved in the demo cases.

1.4 Structure of the document

This document is structured as follows:

Section 1 constitutes a description about the purpose and the scope of deliverable D8.4, as well as the SYNERGY Evaluation Framework Methodology. A description of each microprocess included in the overall work plan is given, along a presentation of the tools that were utilized in order to facilitate the task's implementation.

Section 2 provides an overview of the state-of-the-art evaluation methodologies, embracing the most well-known Energy and PMV methodologies, Cost Benefit Analysis Framework and Data Quality Evaluation Methodologies.

Section 3 of the document is dedicated to the SYNERGY Generic Evaluation Framework. At first, an elaboration of the evaluation perspectives is provided, as it surfaces from the already defined project use cases, demo cases, and business scenarios in deliverables D2.2 and D10.1 of the SYNERGY project. Later on, the KPIs calculation methodology is given, along with the KPIs definition process and SYNERGY PMV perspectives, The final list of SYNERGY KPIs is provided in Section 3.2 and the complete description of the KPIs is disposed in Annex I.

Section 4 presents the SYNERGY Technical Validation, providing a list of KPIs related to data quality and data functionality following ISO/IEC 25010 and 25012. A business validation approach and a data monitoring approach is also provided.

Section 5 comprises the demo validation scenarios for the project defined demo cases. The validation scenarios bring together the different innovative energy applications and data analytics proposed by the SYNERGY platform, propose relevant impact KPIs to the demo scenarios and an evaluation plan to

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comprehensively assess the impact of SYNERGY solutions and tools upon their BaU operational strategies.

Section 6 concludes the document.

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2 Overview of evaluation methodologies

2.1 Energy/PMV methodologies

Measurement and Verification

"Measurement and Verification" (M&V) in the energy sector is the collection of methods and processes that measure, collect and analyze data in order to verify and report the energy savings of a particular energy facility, application, project, etc. by implementing energy conservation measures (ECMs). The development of a collection originates from the need to determine the energy savings from an energy project, since it is a quantity that cannot be directly measured. Generally, savings are calculated by comparing consumption or demand before and after the implementation of a project, making appropriate adjustments for changes in conditions. The comparison between before and after energy use should be made on a constant basis, applying the following general M&V equation:

Savings = (Baseline Period Energy – Reporting Period Energy) ± Adjustments

With the calculation of these savings, the M&V can demonstrate how much energy an applied ECM has avoided consuming.

The main objectives of a M&V process are the following:

- performance assessment of an energy efficiency program or project
- measurement of the energy or demand savings
- determination of whether or not a specific energy program is generating the expected level of savings.

M&V typical activities include some or all of the following:

- meter installation, configuration and maintenance,
- data collection and screening,
- development of a calculation method and acceptable estimation,
- computations with measured data, and
- reporting, quality assurance, and third-party verification of reports.

M&V methods require well-defined, disciplined and transparent processes to determine the energy savings and efficiency along with the best practices that fit well in each use case. For this reason,

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several European and international standards and protocols on energy M&V techniques have been developed that clarify and standardize the necessary processes that have to be performed towards the energy savings and efficiency estimation. Some of them include the International Performance Measurement and Verification Protocol (IPMVP) developed by EVO, the Federal Energy Management Program (FEMP) M&V guidelines (version 2.2) from the U.S. Department of Energy (DOE) and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) M&V protocol. A literature review of these three protocols is presented in the following sections

2.1.1 International performance measurement and verification protocol

In the previous section, it is stated that savings cannot be directly measured, because savings represent the absence of energy consumption or demand and the general M&V formula was introduced. However, these are general guidelines for the calculation of energy savings that derive from implementing energy conservation measures (ECMs) and do not efficiently apply to any case. Good practice requires that M&V is well integrated into the process of identifying, developing, procuring, installing and operating energy conservation measures. For this goal, the IPMVP's framework [4] has been developed in order to define standard terms and suggest best practise for quantifying the results of energy efficiency investments. For the development of the IPMVP, a group of several international organizations, led by the United States Department of Energy, have cooperated since 1994-1995. This framework has become the national measurement and verification standard in the United States and many other countries.

The main goals of the IPMVP are the following:

- increase in certainty, reliability, and level of savings,
- reduction of transaction costs by offering an international, industry consensus approach and methodologies,
- reduction of financial costs by providing a project with a Measurement and Verification Plan (M&V Plan) standardisation,
- provision of a basis for demonstrating emission reduction and delivering enhanced environmental quality;
- provision of a basis for negotiating the contractual terms to ensure that an energy efficiency project achieves or exceeds its goals of saving money and improving energy efficiency.

The IPMVP is divided into the following three volumes: (i) Volume I named "Concepts and Options for Determining Energy and Water Savings", where the basic concepts are included and the methodology to be carried out is developed, (ii) Volume II named "Concepts and practices for improved indoor environmental quality (2002)", which addresses the environmental aspects of indoor air that are related to the design, implementation and maintenance of Energy Efficiency Measures (EEMs) and (iii) Volume III which provides details for the M&V methods in the construction of new buildings and in renewable energy systems. Since Volume I includes most of the information needed to apply the IPMVP it is considered the most important one and thus, this document is referred mainly to Volume I.

It has been clarified that energy savings cannot be directly measured, because they are related to the absence of energy consumption. Thus, the indicated way to calculate the savings deriving from the implementation of an ECM/EEM is to compare the consumption between the following two periods of time:

- **Reference period**: this is the initial period and is the one before the implementation of the ECM/EEM. The main target in this period is to determine the standard consumption curve, as it would be involved without any ECM/EEM. Measuring baseline data is a costly task, and the quality of the decisions can impact on the accuracy and validity of conclusions on energy savings. Depending on the independent variables affecting the consumption which is targeted, different decisions will be taken about the appropriate length of baseline – day, week, month or year. Therefore, independent variables like outside temperature, hours of operation, occupancy, length and timing of baseline measurement, etc., play a significant role during this period.
- **Reporting period**: it refers to the period after the implementation of a particular ECM/EEM or a group of them. During this period, the consumption curve (called adjusted baseline) will be estimated based on the reference baseline identified in the previous period and corrected according to some independent variables that will have a significant impact (e.g. outside temperature, hours of operation, occupancy, etc.). Finally, the actual consumption is measured and it is compared to the adjusted baseline curve. The difference between them in the reporting period will define the savings achieved.

The aforementioned methodology that is used within IPMVP framework to estimate energy/demand savings, is illustrated in the following figure:

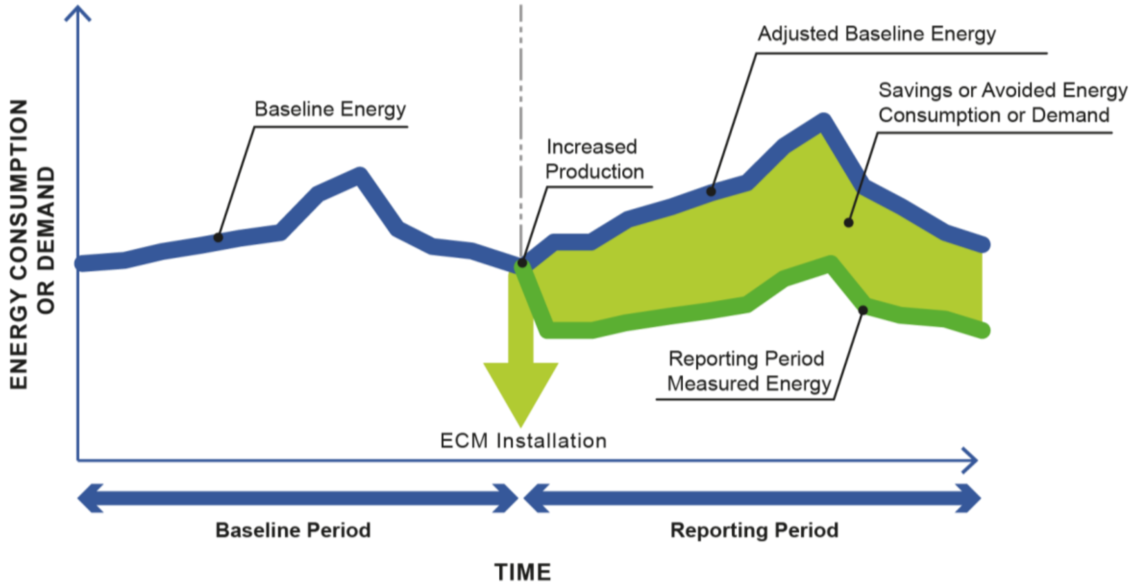

Figure 2: IPMVP framework [4]

Depending on aspects such as scope, available data, measurement equipment available, type of installation, budget for the M&V or the EEM itself, the following four options (A-D) are given within the IPMVP framework to calculate the savings:

Table 1: IPMVP options for savings calculation

Approaches	Definition	Savings calculation	Typical Applications
Option A – Retrofit Isolation: Key Parameter Measurement	The key performance parameters are defined in order to collect their partial field measurements and determine the energy savings. Field measurements indicate the partial energy consumption and demand of the system(s) to which an ECM was applied, separate from the energy use of the rest of the facility. Parameters not included in the field measurements have to be estimated. Estimations are based on historical data, manufacturer's specifications, or engineering judgment. Documentation of the source or justification of the estimated parameter is mandatory.	Engineering calculations using measurements and stipulations from the baseline period and the reporting period.	Lighting retrofit where power absorbed is measured periodically while operating hours of the lights are estimated.

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Approaches	Definition	Savings calculation	Typical Applications
	The potential estimation error is evaluated.		
		Measurement frequency varies from short-term to continuous, based on the expected variations in the measured parameter and the length of the reporting period.	
Option B – Retrofit Isolation: All Parameter Measurement	Similar to option A, except that all key performance parameters which define the energy consumption and demand of the ECM-affected system energy savings have to be measured.	Similar to option A.	Lighting retrofit where both power absorbed and the operating hours are tracked.
Option C – Whole Facility	Energy savings are determined by measuring the energy use at the whole facility or sub-facility level.	Analysis of whole facility utility meter or sub-meter data applying methodologies from simple comparison to regression analysis.	Multifaceted energy management program affecting many systems in a building. Energy use is measured by the gas and electric utility meters for a twelve month base-year period and throughout the post-retrofit period.
	The utility meters from energy suppliers (e.g. gas, electric) are used for the savings calculations to define the baseline.	Continuous measurements of the entire facility's energy use are recorded throughout the reporting period.	
Option D – Calibrated Simulation	Energy savings are not determined by measurements but through simulation of the energy use of the whole facility, or of a sub-facility	Energy use simulation, calibrated with hourly or monthly utility billing data and/or end-use metering.	Multifaceted energy management program affecting many systems in a building but without base-year data are available. Post-retrofit period energy use is measured by the gas and electric utility meters.
	This calibrated simulation is performed using professional software. The software models the building's performance and calibrated simulations are used to determine the targeted system's energy consumption and demand.		

2.1.2 Federal Energy Management Program (FEMP)

The Federal Energy Management Program (FEMP) [5] is a U.S. Department of Energy (DOE) program focused on reducing the federal government's energy consumption of their buildings by providing specific methods and directives for the measurement and verification of energy savings and meeting energy related requirements and goals. To reach its objective, FEMP encourages the use of technical and investment experts from the private sector through performance contracts. FEMP seeks contracts with small businesses to aid in this effort. This fact sheet outlines essential resources and tips to get started in small business contracting with FEMP. FEMP indicates the following six steps to measure and verify savings:

1. **Allocate Project Risks and Responsibilities:** The basis of any project-specific M&V plan is determined by the allocation of key project risks of financial, operational, and performance issues and responsibilities between the ESCO and the customer involved.
2. **Develop a Project-Specific M&V Plan**: The M&V plan defines how savings will be calculated and specifies any ongoing activities that will occur after equipment installation. The project-specific M&V plan includes project-wide items as well as details for each EEM.
3. **Define the Baseline**: Baseline physical conditions (such as equipment inventory and conditions, occupancy schedule, nameplate data, equipment operating schedules, key energy parameter measurements, current weather data, control strategies, etc.) are determined through surveys, inspections, spot measurements, and short-term metering activities. It is very important to properly define and document the baseline conditions. Deciding what needs to be monitored (and for how long) depends on such factors as the complexity of the measure and the stability of the baseline, including the variability of equipment loads and operating hours, and the other variables that affect the load.
4. **Install and Commission Equipment and Systems**: Commissioning ensures that systems are designed, installed, functionally tested in all modes of operation, and capable of being operated and maintained in conformity with the design intent (appropriate lighting levels, cooling capacity, comfortable temperatures, etc.).
5. **Conduct Post-Installation Verification Activities**: Post-installation M&V activities are conducted to ensure that proper equipment/systems were installed, are operating correctly, and have the potential to generate the predicted savings. Verification methods include surveys, inspections, spot measurements, and short-term metering.

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6. **Perform Regular-Interval M&V Activities**: M&V is required to be performed on an annual basis. With proper coordination and planning, M&V activities that provide operational verification of an EEM (i.e., confirmation that the EEM is operating as intended) during the performance period can also support ongoing commissioning activities (e.g., recommissioning, retro-commissioning, or monitoring-based commissioning).

Moreover, the project manager can choose different measurement and verification methods, based on the conditions of each case, in order to select the option that best describes the situation and use the method provided to prove the savings of the energy conservation measures implemented. These measurement and verification options are presented in the following table.

Table 2: FEMP MV options:

Approaches	Description
Option A – Key Parameter Measurements	This method applies to the system affected by the energy conservation measures implemented. To calculate the energy savings, certain parameters will be measured and other will be estimated using the building's history or the manufacturer's specifications. Estimates alone can be used for this option as well, but the measurement of parameters is strongly recommended.
Option B – All Parameter Measurement	This method applies to the system affected by the energy conservation measures implemented. All necessary parameters must be measured to calculate the energy savings.
Option C – Utility Data Analysis	This method applies to an entire facility. The energy savings are calculated using the energy suppliers' meters.
Option D – Calibrated Computer Simulation	This method can apply to an entire facility or to the subsystems affected by the energy conservation measures. Energy savings are measured using a simulation based on engineering estimates, equipment changes and the building's utility meters data.

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2.1.3 American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) M&V protocol

ASHRAE developed Guideline 14-2014, Measurement of Energy, Demand, and Water Savings [6] to facilitate the standardization of the calculation processes. Its main objective is to "provide guidelines for reliably measuring the energy, demand, and water savings achieved in conservation projects." It was developed to standardize the savings calculations resulting from energy conservation and reduction measures. ASHRAE Guideline 14 creates particular processes for using measured pre-retrofit and post-retrofit billing data (kWh, kW, etc.) for the calculation of savings. This protocol is exhaustive and technically in-depth since it was developed by a group of technical experts. It includes documentation on measurement instruments, uncertainty estimates, regression analysis techniques and examples of approaches for different systems.

The ASHRAE Guideline 14-2014 processes include:

●the calculation of energy, demand, and water savings from specific facilities or applications,

●implementation to all types of energy (e.g. electricity, gas, oil, district heating/cooling, renewables, and water), and every category of facilities (commercial, industrial, and residential).

The ASHRAE Guideline 14 included three different approaches to estimate savings coming from an energy conservation measure. These approaches are illustrated in the following table.

Table 3 ASHRAE approaches

Approaches	Description
Entire Building	This approach uses the main utility meter, usually installed by the electricity, gas, oil or hot water supplier. The energy savings measures can affect one or more of the building's subsystems. Use of the billing history is often necessary to define the baseline.
Retrofit Isolation	This method uses measurement equipment to isolate the energy and relevant independent variables used by the individual systems that are affected by the applied ECM. The baseline scenario is also required which is defined by measuring the system before the installation of the ECM to illustrate the full range of impact.

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Approaches	Description
Calibrated Simulation of the Entire Building	This approach consists of the use of a computer simulation tool to develop a consumption and energy demand model for the entire building. The resulting energy is acquired by the parameters that are affected by the ECM and are modified in the developed model.

2.2 Cost Benefit Analysis

Cost–Benefit Analysis (CBA) [7] –[9] is performed to evaluate ex ante the implementation of different policy options and support decision makers on selecting the most cost-effective alternative. CBA aggregates the welfare of various stakeholders and actors such as consumers, prosumers, DSOs, Retailers, Aggregators, etc. to obtain an expression for the welfare of the overall society.

CBA provides an overview of the effects, risks and uncertainties of a measure and the resulting costs and benefits to society as a whole. CBA quantifies benefits and drawbacks of suggested features and aims to assign monetary value to them.

CPB Netherlands Bureau for Economic Policy Analysis [7] describes eight generic steps needed to perform CBA on any domain, including smart grids and energy innovative services which are presented below:

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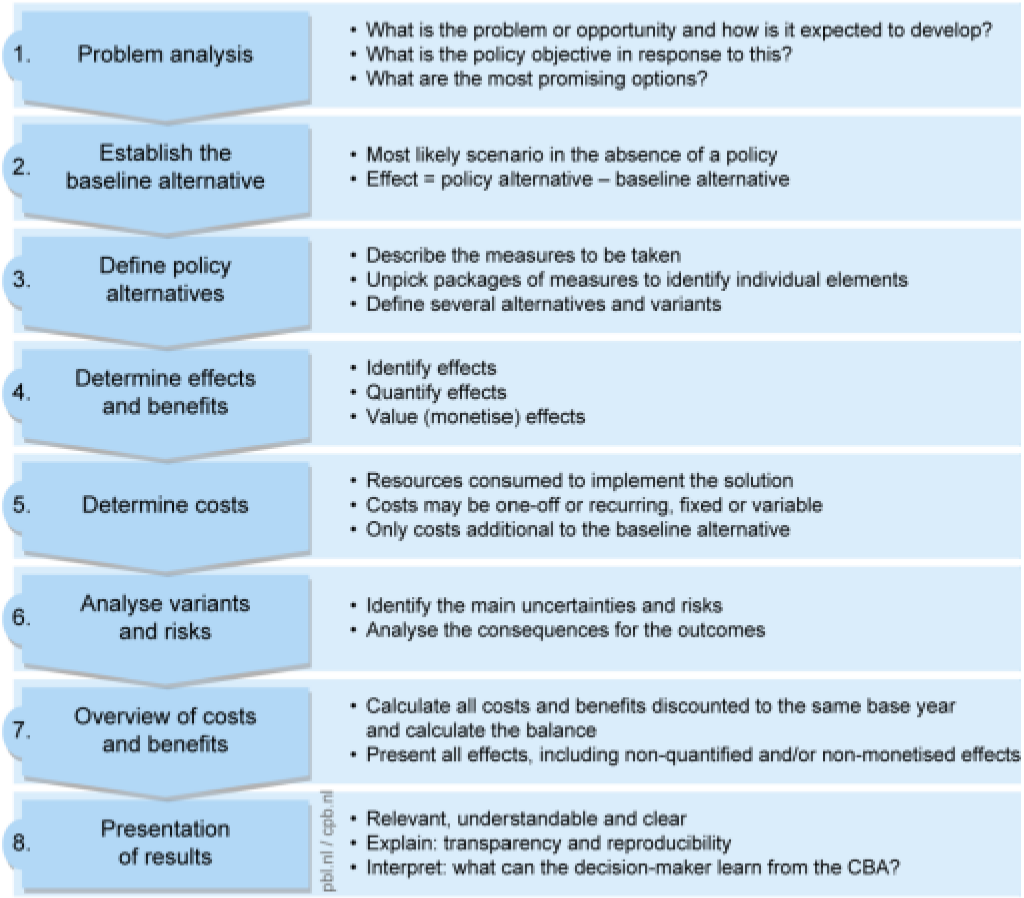

Figure 3: Steps in a CBA according to CPB Netherlands Bureau for Economic Policy Analysis

The preparatory phase includes the first three steps, i.e. problem analysis, establish the baseline alternative and define policy alternatives. The core of the CBA is the determination of effects, benefits and costs (steps 4 and 5). Then the variant and risks are analysed and costs and benefits are calculated (steps 6 and 7). Finally, outcomes are interpreted and presented (step 8).

Preparatory phase of a CBA

The preparatory phase of a CBA consists of 3 main steps:

- The problem analysis: ensures that the CBA addresses the issue under investigation
- Defining the baseline (benchmark): is the most likely situation that would develop if the measure under consideration were not implemented
- Defining the solution alternatives: contains the measure to be implemented. It is expected to be technically and economically feasible and has a credible relation with the problem identified in the problem analysis

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Determination of effects, benefits and costs

The determination of effects and their associated benefits takes place in three steps: identifying the effects, quantifying the effects and valuing the effects:

- Identification of effects: establishing what effects a measure has and determining which of these are of significance for the CBA.
- Quantification of effects: methods for determining the effects include behavioral models, business cases, experiments and calculation of indexes
- Costs: the costs of a measure are made up of the costs of resources required to implement and sustain it
- Quantification of benefits: Calculate quantitative estimates of the benefits and use economic conversion factors to estimate the monetary value of the benefits

Compare costs to benefits

- Valuation of effects: Perform cost benefit analysis by comparing the estimated calculated costs to the monetized benefits

In the same context, the Joint Research Centre (JRC) has prepared a report that focuses on smart meters that constitute the core element of Smart Grids and particularly on Smart Metering Deployment projects [8],[9].

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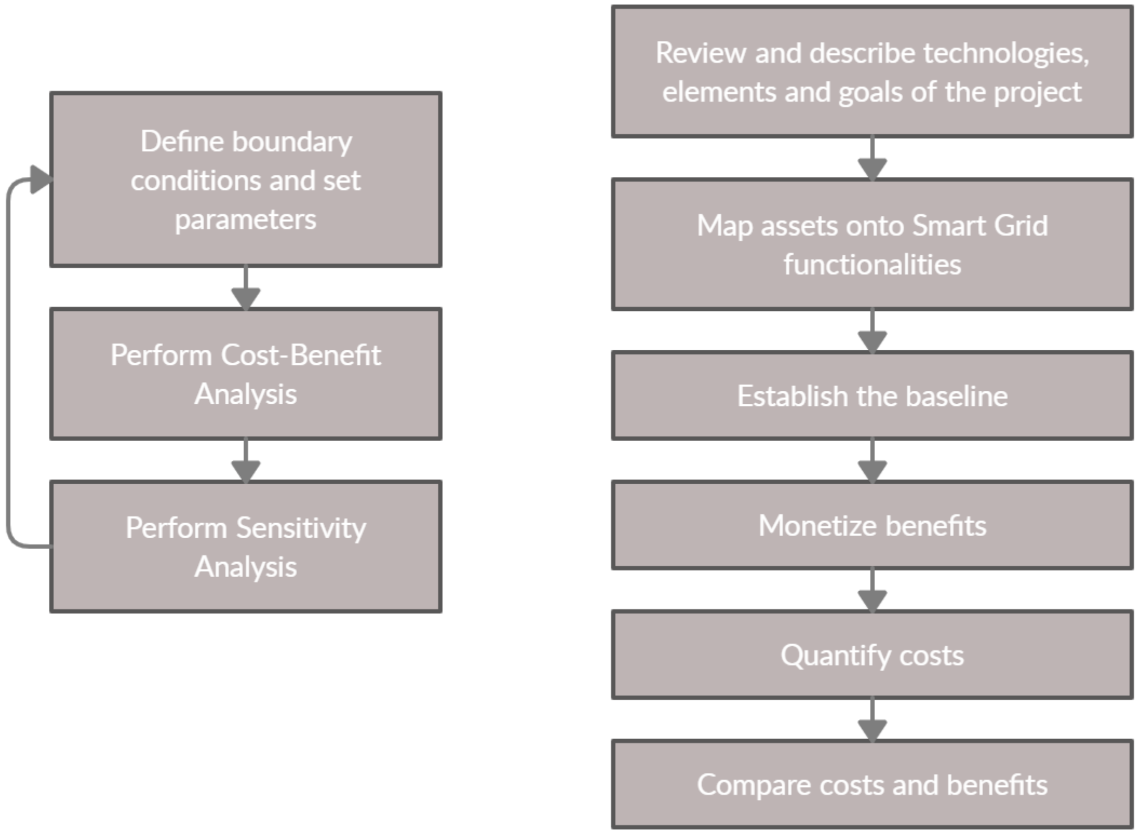

Figure 4: The Cost-Benefit Analysis Framework according to EU JRC

According to EU JRC evaluation framework [8],[9]

- Benefits should represent those actually resulting from the project
- Benefits should have meaningful impact
- The individual benefit and cost variables should be mutually exclusive
- The level of uncertainty associated to the benefit estimation should be clearly stated and documented
- The beneficiaries (consumers, system operators, society, retailers etc.) associated with each benefit should be identified

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2.3 Data Quality Evaluation Methodologies

2.3.1 ISO/IEC 25010:2011

Code quality frameworks describe which quality characteristics will be taken into account when evaluating the properties of a software product. Such frameworks are the key element for a product quality evaluation system. For Enterprise software development, one model stands out: the ISO/IEC 25010 [10], which was launched in 2011.

Software quality reflects the degree to which the software conforms to the stated and implied needs of its various stakeholders. Those stakeholders' needs are exactly the characteristics and sub-characteristics that are represented in the quality model. Within the characteristics, the software can be assessed to verify if it can be tested simply, it is easy to understand/follow and if it is easy to edit and upgrade without introducing new errors.

ISO/IEC 25010 describes two quality models:

1.The quality in use model is composed of five characteristics (some of which are further sub-divided into sub-characteristics) that relate to the outcome of interaction when a product is used in a particular context of use.

2.A product quality model is composed of eight characteristics (which are further sub-divided into sub-characteristics) that relate to static properties of software and dynamic properties of the computer system.

The product quality model characteristics is shown in the following figure:

Figure 5: Software product quality characteristics according to ISO/IEC 25010

An overview of each characteristic and sub-characteristic is presented in the following paragraphs:

Functional Suitability

Functional Suitability means how well a product or system is able to provide functions that meet the stated and implied needs.

- Functional Completeness: Refers to the set of functions that covers all of the specified tasks and user objectives.
- Functional Correctness: describes how well a product or system provides the correct results with the needed degree of precision.
- Functional Appropriateness: Refers to how well functions are able to accomplish specified tasks and objectives.

Reliability

Reliability refers to how well a system, product, or component performs specified functions under specified conditions.

- Maturity: degree to which a system, product or component meets needs for reliability under normal operation.
- Availability: degree to which a product or system is operational and accessible when required for use.
- Fault tolerance: degree to which a system, product or component operates as intended despite the presence of hardware or software faults.
- Recoverability: degree to which, in the event of an interruption or a failure, a product or system can recover the data directly affected and re-establish the desired state of the system.

Performance Efficiency

This characteristic represents the performance relative to the amount of resources used under stated conditions. This characteristic is composed of the following sub-characteristics:

- Time behaviour: Degree to which the response and processing times and throughput rates of a product or system, when performing its functions, meet requirements.
- Resource utilization: Degree to which the amounts and types of resources used by a product or system, when performing its functions, meet requirements.

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- Capacity: Degree to which the maximum limits of a product or system parameter meet requirements.

Useability

Degree to which a product or system can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use. This characteristic is composed of the following sub-characteristics:

- Appropriateness recognizability: Degree to which users can recognize whether a product or system is appropriate for their needs.
- Learnability: Degree to which a product or system can be used by specified users to achieve specified goals of learning to use the product or system with effectiveness, efficiency, freedom from risk and satisfaction in a specified context of use.
- Operability: Degree to which a product or system has attributes that make it easy to operate and control.
- User error protection: Degree to which a system protects users against making errors.
- User interface aesthetics: Degree to which a user interface enables pleasing and satisfying interaction for the user.
- Accessibility: Degree to which a product or system can be used by people with the widest range of characteristics and capabilities to achieve a specified goal in a specified context of use.

Security

Degree to which a product or system protects information and data so that persons or other products or systems have the degree of data access appropriate to their types and levels of authorization. This characteristic is composed of the following sub-characteristics:

- Confidentiality: Degree to which a product or system ensures that data are accessible only to those authorized to have access.
- Integrity: Degree to which a system, product or component prevents unauthorized access to, or modification of, computer programs or data.
- Non-repudiation: Degree to which actions or events can be proven to have taken place so that the events or actions cannot be repudiated later.
- Accountability: Degree to which the actions of an entity can be traced uniquely to the entity.

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- Authenticity: Degree to which the identity of a subject or resource can be proved to be the one claimed.

Compatibility

Compatibility refers to how well a product, system, or component can exchange information as well as perform its required functions while sharing the same hardware or software environment.

- Co-existence: Refers to how well a product can perform its required functions efficiently while sharing a common environment and resources with products, without negatively impacting any other product.
- Interoperability: Refers to how well two or more systems, products, or components are able to exchange information and use that information.

Maintainability

Maintainability refers to how well a product or system can be modified to improve, correct, or adapt to changes in the environment as well as requirements.

- Modularity: Refers to whether the components of a system or program can be changed with minimal impact on the other components.
- Reusability: Refers to how well an asset can be used in more than one system.
- Analysability: Refers to the effectiveness of an impact assessment on intended changes. In addition, it also refers to the diagnosis of deficiencies or causes of failures, or to identify parts to be modified.
- Modifiability: Refers to how well a product or system can be modified without introducing defects or degrading existing product quality.
- Testability: Refers to how effective the test criteria is for a system, product, or component. In addition, it also refers to the tests that can be performed to determine whether the test criteria have been met.

Portability

Portability refers to how well a system, product, or component can be transferred from one environment to another.

- Adaptability: Refers to how well a product or system can be adapted for different or evolving hardware, software, or other usage environments.

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- Installability: Refers to how successfully a product or system can be installed and/or uninstalled.
- Replaceability: Refers to how well a product can replace another comparable product.

An overview of the quality in use model characteristics and sub-characteristics is presented in the following paragraphs:

Effectiveness: It refers to the accuracy and completeness with which users achieve specified goals.

Efficiency: It refers to the resources expended in relation to the accuracy and completeness with which users achieve goals.

Satisfaction: It refers to a series of factors that make users satisfied with the software.

- Usefulness: degree to which a user is satisfied with their perceived achievement of pragmatic goals, including the results of use and the consequences of use.
- Trust: degree to which a user or other stakeholder has confidence that a product or system will behave as intended.
- Pleasure: degree to which a user obtains pleasure from fulfilling their personal needs.
- Comfort: degree to which the user is satisfied with physical comfort.

Freedom from Risk: It refers to a series of risks that are related to the software.

- Economic Risk Mitigation: degree to which a product or system mitigates the potential risk to financial status, efficient operation, commercial property, reputation or other resources in the intended contexts of use.
- Health and Safety Risk Mitigation: degree to which a product or system mitigates the potential risk to people in the intended contexts of use.
- Environmental Risk Mitigation: degree to which a product or system mitigates the potential risk to property or the environment in the intended contexts of use.

Context coverage: Context coverage consists of the following sub-characteristics.

- Context Completeness: degree to which a product or system can be used with effectiveness, efficiency, freedom from risk, and satisfaction in all the specified contexts of use.

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- Flexibility: degree to which a product or system can be used with effectiveness, efficiency, freedom from risk and satisfaction in contexts beyond those initially specified in the requirements.

2.3.2 ISO/IEC 25012

ISO/IEC 25012 [11] establishes a general data quality model for structured data that is handled by an Information & Communication system. The Data Quality model defines the main principles for assessing the quality of data products. In a Data Quality model, the main Data Quality characteristics, e.g. data quality requirements, data quality measures, etc. have to be considered in order to assess the intended properties of the data product. For example, Data Quality model can be used:

- to define and evaluate data quality characteristics in data production, acquisition and integration processes,
- to identify data quality assurance criteria, also useful for re-engineering, assessment and improvement of data,

The Quality of a Data Product can be perceived as the point to which data meet the requirements that are set by the product-owner organization. In this way, the requirements of the product-owner organization are measured through the characteristics of the Data Quality model, e.g. accuracy, completeness, consistency, credibility, currentness, etc. ISO/IEC 25012 classifies quality attributes into fifteen characteristics considered by two points of view: inherent and system dependent. These characteristics are shown in the picture below:

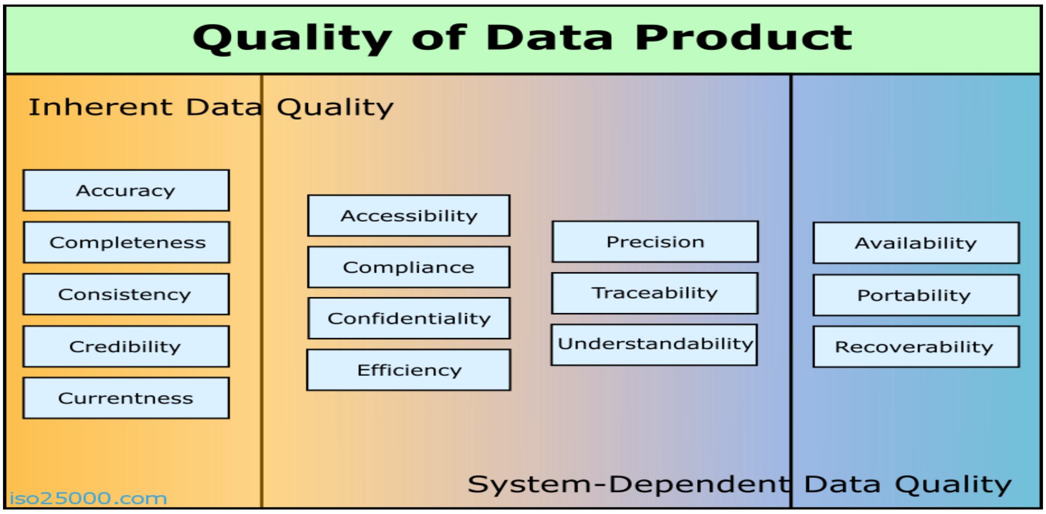

Figure 6: Quality of Data Product according to ISO/IEC 25012

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Inherent data quality refers to the degree to which quality characteristics of data have the intrinsic potential to satisfy stated and implied needs when data is used under specified conditions. From the inherent point of view, data quality refers to data itself, in particular to:

- data domain values and possible restrictions (e.g. business rules governing the quality required for the characteristic in a given application);
- relationships of data values (e.g. consistency);
- metadata.

System dependent data quality refers to the degree to which data quality is reached and preserved within a computer system when data is used under specified conditions.

From this point of view, data quality depends on the technological domain in which data are used; it is achieved by the capabilities of computer systems' components such as:

- hardware devices (e.g. to make data available or to obtain the required precision),
- computer system software (e.g. backup software to achieve recoverability), and
- other software (e.g. migration tools to achieve portability).

A brief presentation of the Data Quality model characteristics, classified by inherent and system dependent points of view, is following:

Inherent Data Quality

Accuracy: The degree to which data has attributes that correctly represent the true value of the intended attribute of a concept or event in a specific context of use. It has two main aspects:

- **Syntactic Accuracy:** Syntactic accuracy is defined as the closeness of the data values to a set of values defined in a domain considered syntactically correct.
- **Semantic Accuracy:** Semantic accuracy is defined as the closeness of the data values to a set of values defined in a domain considered semantically correct.

- **Completeness:** The degree to which subject data associated with an entity has values for all expected attributes and related entity instances in a specific context of use.
- **Consistency:** The degree to which data has attributes that are free from contradiction and are coherent with other data in a specific context of use. It can be either or both among data regarding one entity and across similar data for comparable entities.
- **Credibility:** The degree to which data has attributes that are regarded as true and believable by users in a specific context of use. Credibility includes the concept of authenticity (the truthfulness of origins, attributions, commitments).
- **Currentness:** The degree to which data has attributes that are of the right age in a specific context of use.

Inherent and System-Dependent Data Quality

- **Accessibility:** The degree to which data can be accessed in a specific context of use, particularly by people who need supporting technology or special configuration because of some disability.
- **Compliance:** The degree to which data has attributes that adhere to standards, conventions or regulations in force and similar rules relating to data quality in a specific context of use.
- **Confidentiality:** The degree to which data has attributes that ensure that it is only accessible and interpretable by authorized users in a specific context of use. Confidentiality is an aspect of information security (together with availability, integrity) as defined in ISO/IEC 13335-1:2004.
- **Efficiency:** The degree to which data has attributes that can be processed and provide the expected levels of performance by using the appropriate amounts and types of resources in a specific context of use.
- **Precision:** The degree to which data has attributes that are exact or that provide discrimination in a specific context of use.
- **Traceability:** The degree to which data has attributes that provide an audit trail of access to the data and of any changes made to the data in a specific context of use.
- **Understandability:** The degree to which data has attributes that enable it to be read and interpreted by users, and are expressed in appropriate languages, symbols and units in a

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specific context of use. Some information about data understandability are provided by metadata.

- **Availability:** The degree to which data has attributes that enable it to be retrieved by authorized users and/or applications in a specific context of use.
- **Portability:** The degree to which data has attributes that enable it to be installed, replaced or moved from one system to another preserving the existing quality in a specific context of use.
- **Recoverability:** The degree to which data has attributes that enable it to maintain and preserve a specified level of operations and quality, even in the event of failure, in a specific context of use.

2.4 Discussion

The SYNERGY evaluation and technical validation framework borrows elements from all approaches described in the previous subsections in order to capture all important details of a pilot study and plan the demonstration activities in an effective and successful way.

As part of the "Cost Benefits" analysis, the SYNERGY evaluation framework is expected to analyse all the expected SYNERGY products, such as the energy innovative applications, the SYNERGY Big Data Platform and defined demo cases. This will be accomplished through the well-defined SYNERGY KPIs, which, through their definition and calculation formulas, allow the comparison between the BaU state of the demos with the state after the implementation of various SYNERGY tools, reflecting the added value provided by the functionalities of the involved tools. The same methodological framework as defined and described within EU JRC activities, the CPB Netherlands Bureau, and other EU projects , such as NOBELGRID, WISEGRID and CoordiNET.

Regarding the SYNERGY applications and analytics addressing forecasting aspects, appropriate KPIs have been defined and formulated to measure the accuracy of the forecasting algorithms (considering generation, demand and flexibility forecasting). The forecasting models will be defined and tested during the project to achieve a standard algorithm for the baseline construction that can be applied to different types of users and dwellings as well as in different climate conditions. The accuracy of the developed models will be evaluated through the defined KPIs.

The PMV approach to be followed in the SYNERGY project regarding the energy related data and functionalities will have three objectives:

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a) To perform accurate baselining of current energy performance of the energy systems and normalize it against energy uses and climatic conditions. Where appropriate, to define the “Business as Usual” state, used as a comparison benchmark for the state of pilots after the implementation of the SYNERGY project R&I solutions. Characterizing the baseline period would help to identify the situation of the grid ecosystem in the absence of the tools and technology considered in the context of the SYNERGY project. The most common issues for baselining construction are related to the selection of representative days as basis for estimation, setting of exclusion rules to avoid considering non-representative consumption, definition of adjustments’ types and windows.

b) To simulate, measure and verify the improvement on power quality, energy costs, res integration, carbon savings among other aspects achieved due to the SYNERGY innovative energy applications and R&I solutions.

c) To estimate the short/mid-term impact of project activities through a socio-economic analysis initiated for each demo case, through the demo validation scenarios, the impact KPIs related with each demo case and the defined business scenarios which express and identify the market value of the demo cases and the products related to them.

Finally, validation scenarios have been initiated for all the demo cases within SYNERGY to enable representative deployment of the proposed solutions. This process gives the stakeholders the opportunity to obtain valuable insights whether their target objectives were met, or additional adjustments are needed when it comes to project overall objectives and the interests of their business.

- The validation scenarios template has been designed in such a way to provide a high-level overview of the messages, data and functionalities to be exchanged between different stakeholders, including the actors involved and their relationships, the equipment installed and the overall architecture and sequence flow of the project activities which include the utilization of the platform and the energy applications.
- The validation scenarios template also includes a respective reference on the sequence of steps to be followed towards the evaluation of the demo cases, as also demonstrated in other European projects (NobelGrid project) :
    - Planning phase / Before Implementation
    - Commissioning phase / During Implementation
    - Performance Monitoring phase/ After Implementation

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3 SYNERGY Generic Evaluation Framework

SYNERGY brings innovation in the ICT and the Energy sectors, aiming to create a new mentality for the electricity data value chain built on sharing data assets. The energy applications delivered through the technical work packages WP5, WP6, WP7 and the Big Energy Data Platform and AI Analytics Marketplace (delivered in WP3 and WP4) aim to offer end-to-end services, across the whole value chain and actors involved. A list of benefits that SYNERGY aspires to provide to the energy stakeholders involved are summarized in the table below:

Table 4 : SYNERGY project benefits as they are identified in the description of action

Benefits for Network Operators	➢ Peak Load Reduction and Avoidance of Grid Congestions ➢ Self-consumption relieves grid from losses and instability ➢ Optimized Flexibility Control alleviates RES-originating instabilities and reduces the need for grid reinforcement ➢ Improvement of Overall Reliability and Performance of Distribution/Transmission Grids
Benefits for Prosumers (incl. Facility Managers and City authorities) and local communities	➢ Revenues from flexibility utilization and trading ➢ Reliability improvement boosting trust and local economies ➢ Cost savings through intelligent control ➢ Human-centric comfort preservation ➢ Easy and transparent participation of prosumers in energy markets
Benefits for RES Operators Facility Managers, ESCOs and City authorities	➢ Optimized asset management of RES plants and Large Facilities ➢ Reinforcement of the effectiveness and re-risking of the viability of Energy Performance Contracting for ESCOs ➢ Advanced observability and monitoring of energy performance over entire districts and cities and facilitation of urban planning processes towards

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	realizing smart city commitments in the short- and mid-term
Benefits for entire districts and cities	➢ Significant reduction of imbalance charges ➢ Larger trackable energy savings that will alleviate political and policy pressure

Following the SYNERGY methodological approach to deliver the envisaged innovation, a set of use cases have been defined within D2.2 ‘End-user and Business requirements analysis for big data-driven innovative energy services and ecosystems v2’, which reflect the functionalities offered by the energy services and the SYNERGY big data platform and encapsulate the actors’ interactions and overall project objectives.

Additionally, a set of business scenarios has been developed within the same deliverable D2.2. The business scenarios developed in SYNERGY reflect the high-level, contextual business value that is expected to be derived for each of the electricity market actors from the SYNERGY big data platform and AI analytics marketplace. The defined business scenarios provide the basis upon which the transformation of the electricity sector towards a data sharing mentality and data-driven electricity services, will be enabled via the functionalities of the SYNERGY platform. The SYNERGY business scenarios are summarized in the table below.

Table 5: SYNERGY Business Scenarios as they are identified in D2.2

Business Scenarios	
AG -BS1: Aggregators to optimize their positioning in flexibility markets and hedge their risks through fine-grained flexibility segmentation, classification and clustering towards VPP configuration for human-centric demand response	**RE-BS1**: Electricity retailers to increase their profitability and improve their business sustainability through their transformation into energy service providers (rather than pure commodity providers) with the use of advanced portfolio analytics **RE-BS2**: Electricity retailers to increase competitiveness of their tariff schemes and increase revenues and profits through advanced energy analytics that facilitate the establishment of GPPAs

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TSO-BS1: Transmission system operators to reduce OPEX and safeguard security of supply and quality of service through improved DER forecasts and flexibility analytics in the frame of Flexibility-based network management and collaborative flexibility scheduling with DSOs **TSO-BS2:** Transmission system operators to reduce total cost of ownership and effectively safeguard network availability and resilience through advanced network asset management analytics (incl. predictive maintenance, network planning and sizing)	**DSO-BS1:** Distribution system operators to reduce OPEX and safeguard security of supply and quality of service through improved DER forecasts and flexibility analytics in the frame of Flexibility-based network management and collaborative flexibility scheduling with TSOs **DSO-BS2:** Distribution system operators to reduce total cost of ownership and effectively safeguard network availability and resilience through advanced network asset management analytics (incl. predictive maintenance, network planning and sizing)
ESCO-BS1: ESCOs to increase the attractiveness of renovation investments and reduce EPC risks, through enhancing the accuracy of Energy Performance Simulations at the design phase and as a means to reduce the gap between anticipated and actual energy performance of buildings **ESCO-BS2:** ESCOs to generate new income through improving existing Energy Performance Certification services and complementing them with Smart Readiness Certification offerings on the basis of highly granular, real-time energy analytics	**RES-BS1:** RES Plant Operators to reduce LCOE (Levelized Cost of Energy) of the RES plants along with the O&M costs, while increasing RES technology reliability, availability and efficiency through advanced asset management and predictive maintenance analytics **RES-BS2:** RES Plant Operators to improve their revenue stream and increase profitability in the short- and long-term through advanced generation and flexibility analytics for increasing accuracy of bids in energy markets, promoting long-term GPPAs and getting involved into flexibility market transactions
CA-BS1: City authorities to optimize their long-term planning and achievement of sustainability goals through accurate forecasting-driven urban planning **PS-BS1:** Prosumers to enjoy significant energy costs savings and safeguard their well-being through fine grained edge analytics facilitating the deployment of personalized energy management and human-centric	**BM-BS1:** Building managers/ Prosumers to generate new income by monetizing their flexibility in local flexibility and energy market transactions through advanced flexibility analytics and trading marketplaces **BM-BS2:** Building Managers/ Facility Managers/ Prosumers to enjoy significant energy cost savings and reduce dependency on the grid through

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automation services, properly balancing energy efficiency and human comfort	individual and coordinated flexibility-based control of building energy systems (generation, storage, demand) for self-consumption maximization

In the same context, D10.1 'Definition of novel data sharing-driven Business Models for Innovative Energy Services v1', has proposed novel business models for energy data value chain stakeholders while also enabling the wide use and application of big data and AI technologies proposed within SYNERGY and considering inputs from the socio-economic and regulatory analysis performed in WP2.

A number of revenue streams has already been identified within D10.1, which indicate the monetary benefits that various actors can gain as electricity/energy market participants while being involved in the respective business models. Revenue streams are summarized below and categorized per actor type:

Table 6: Revenue Streams for various SYNERGY stakeholders as they are identified in D10.1

Revenue streams for Network Operators	➢ Lower operation and maintenance costs ➢ Reduced penalties due to interruptions and local failures (Lost Load) caused by equipment health issues ➢ Indirect revenues (savings) from the enhancement of the quality of power in the network (avoidance of need for additional services for frequency and voltage regulation) and the reduction of power losses (more power delivered) ➢ Reduced balancing costs ➢ Lower energy losses ➢ Lower economic investment for network expansion ➢ Resource savings from better operational efficiency ➢ Reduced penalties for capacity allocation and congestion events. ➢ Postpone investment for network expansion and reinforcement to manage an ever-increasing number of DER
Revenue streams for Prosumers, City	➢ Lower operation and maintenance costs ➢ Indirect revenues through increase of attractiveness of their offering and SLA compliance

authorities and local communities	➢ Savings from better investment planning ➢ Increased energy cost savings (after the EPC period)
Revenue streams for RES Operators Facility Managers, ESCOs and City authorities	➢ Increased revenues due to increased power production (avoidance of losses in power generation) ➢ Reduce LCOE (Levelized Cost of Energy) ➢ Increasing market competitiveness ➢ Indirect revenues (savings) from improved trading functions and ability to deliver their commodity in wholesale markets. ➢ Future Profits from increased generation and optimal volume allocation in guaranteed PPAs ➢ Revenues from power purchases in the frame of GPPAs ➢ Service fees for operation of the Marketplace ➢ Shares of energy costs savings achieved from the renovation project. ➢ Revenues from consultancy services at the pre-renovation phase (alterative design and design optimization) ➢ Cost savings from the avoidance of the resources required for the conduction of on-site audits. ➢ Service fees (portion of energy savings and network charges reduction on the customer side for energy management optimization and self-consumption maximization. ➢ Revenues from analytics sales to Aggregators
Revenue streams for aggregators	➢ Service fees (for flexibility analytics and VPP formulation) ➢ Revenues from New Service Offerings (Insight sales) to ESCOs, Retailers and Network Operators ➢ Service Fees for Demand Response and Flexibility Activation services ➢ Revenues from flexibility services to Network Operators
Revenue streams for retailers	➢ Revenues from Subscriptions of Prosumers and Facility Managers in Innovative Services ➢ Revenues from Flexibility Services provision to the DSO

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	➢ Monetary savings from the avoidance of imbalance charges ➢ Monetary savings from the avoidance of penalties for non-compliance to EE obligations ➢ Savings from avoidance of intra-day energy purchases (costly trading) ➢ Opportunity for additional services (and respective fees) in collaboration with other partners ➢ Increase of market share (sales volumes) due to enhanced consumer engagement and brand reputation ➢ Revenues from Subscriptions of Prosumers and Facility Managers in Comfort, Health, Well-being services ➢ Revenues from Subscriptions of Prosumers and Facility Managers in Security services ➢ Increase of market share (sales volumes) due to enhanced consumer engagement and brand reputation ➢ Service fees for energy management optimization and self-consumption maximization ➢ Revenues from analytics sales to Aggregators and ESCOs ➢ Portion of flexibility remuneration from Aggregator for offering access to their customers and using equipment that has been incentivized by retailers

3.1 Elaboration of evaluation perspectives

The process for defining the SYNERGY KPIs to be used for the project evaluation followed a global approach, during which outcomes coming from various project activities, such as business scenarios and use cases from WP2, business innovation models from WP10, energy service applications from WP5, WP6, WP7 as well as technical mechanisms and functionalities offered from the SYNERGY core, the platform and the marketplace in WP3 and WP4, have been considered.

The evaluation perspectives that have been identified to map on the project strategic objectives (accommodated through the business scenarios) and expected outcomes are reflected on distinct impact categories and a number of aspects that cover the energy applications features and capabilities.

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SYNERGY KPIs shall be mapped on 4 impact categories: energy, economic, environmental and social, and 23 aspects such as RES integration, network observability and energy efficiency to investigate the impact of the proposed solutions.

The categorization is summarized on the table below:

Table 7: Impact Category and Aspects of SYNERGY KPIs

Impact Category	Aspects	
Energy	➢ Energy Efficiency ➢ Network Quality ➢ Network observability ➢ Network Availability ➢ Capability of Prosumers to become active market players ➢ RES Integration ➢ DER activation ➢ Establishment of advanced Flexibility settlement and Remuneration Methods ➢ Alternative (smart) contract types	➢ Building Renovation facilitation ➢ Urban Planning ➢ Local Energy Communities efficiency ➢ Retailer Portfolio efficiency ➢ Energy Savings ➢ Flexibility ➢ Facility management efficiency ➢ Smart contract handling mechanisms
Economic	➢ Cost Savings ➢ O&M Costs savings	
Environmental	➢ Emissions	
Social	➢ Energy Poverty ➢ Safety ➢ Capability of prosumers to become active market players	

SYNERGY KPIs shall belong to a certain impact category, represent (at least) one of the Aspects presented in Table 7 which reflect SYNERGY strategic objectives, represent the outcomes expected

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from the developments of the energy applications, fulfil the requirements from the demonstration cases and remain in line with the defined business scenarios from D2.2.

3.1.1 Identification of SYNERGY KPIs

In order to measure the contribution of the new solutions proposed by SYNERGY to specific project goals which also abide by to EU vision and evaluate their results, it is necessary to define KPIs. These KPIs shall enable the evaluation of the impact of the proposed solutions in the demonstration sites offered through the energy applications and the utilization of the SYNERGY platform. Furthermore, the calculation methodology of each KPI shall be defined. The general procedure followed to identify the KPIs, is presented in Figure 7.

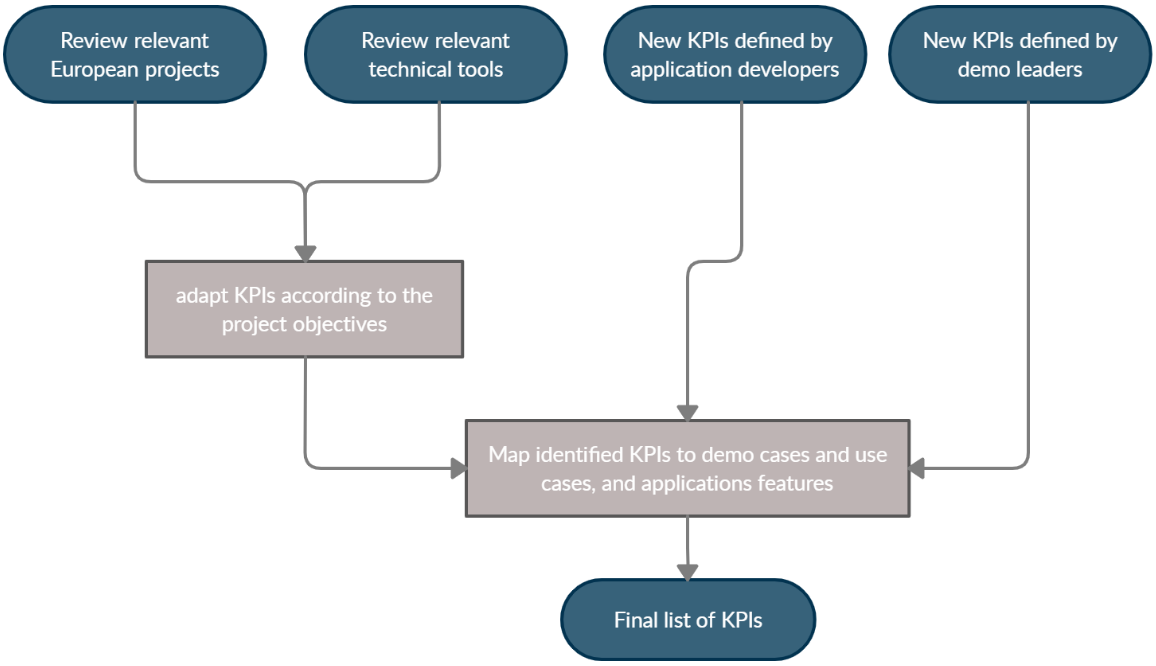

Figure 7: procedure to identify KPIs

3.1.2 KPI calculation methodology

The defined impact KPIs are used to quantify the benefits of R&I projects achievements, delivered through the developed applications and the SYNERGY platform.

According to EEGI Roadmap 2013-2022 [7] and the EEGI framework (developed under the GRID+ project), the EEGI methodology proposes to compare the benefits of applying the R&I solutions with the expected benefits of applying Business as Usual (BaU) solutions. Therefore, BaU solutions, which

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are the solutions using traditional technologies, are used as reference in order to quantify the benefits that are gained by applying the solution proposed by R&I projects.

Assuming that a BaU solution exists, the steps that are followed in order to calculate KPIs in a differential way, are listed below [17]:

1. Determination of the initial condition and identification of the problems that need to be solved or situations that need to be improved.

2. Determination of the possible future situation(s) implementing BaU solutions and estimation of the results and the progress made after applying this approach.

3. Determination of the possible future situation(s) implementing R&I solutions in order to analyze the improvements from applying innovative technologies and estimate the results and the progress made after applying this approach.

4. Calculation of the KPIs by applying the proposed formula for each KPI in order to compare the R&I and BaU solutions.

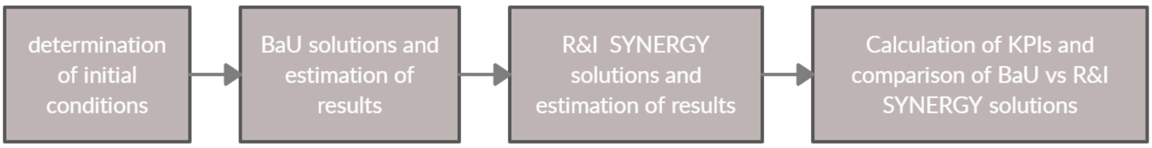

Figure 8: KPI calculation methodology

The comparison between the two states reflects the added value provided by the functionalities of the involved tools.

3.1.3 KPIs definition

For the KPI definition the same template was used by all the application developers. The information needed for the optimal definition of KPIs is categorized and presented as follows:

KPI INFORMATION: The fields included in this category are the main characteristics of the indicator, all the details for its calculation, and its relation with the project use cases, demo cases and energy applications.

1. ID: KPI ID.
2. Name: KPI name.

3. Description: A short description of the KPI, including a description of what the KPI measures and for what it is used.
4. Formula: The formula to calculate the KPI and define all the variables.
5. Unit of measurement: KPI unit of measurement.
6. Related use case(s): List the use case(s) addressed through this KPI.
7. Related demo case(s): List the demo case(s) addressed through this KPI.
8. Related energy app(s): List the energy app (s) addressed through this KPI.

3.2 Definition of SYNERGY KPIs

Following the methodology described in Section 3.1, a total number of **54 KPIs** were identified. The details of the KPIs are presented in **Annex A**. 43 KPIs fall into in the energy impact category, 9 fall into the economic and finally 2 KPIs fall into the environmental category.

Table 8 shows the identified KPIs:

Table 8 : SYNERGY KPIs

KPI ID	KPI name	KPI impact category	KPI aspect
KPI_1	Peak load demand reduction	Energy	Network observability, Network Availability, Power quality (voltage quality, continuity of supply)
KPI_2	Frequency of congestions	Energy	Network Quality, Network Availability
KPI_3	Size of congestions	Energy	Network Quality, Network Availability
KPI_4	Volume of flexibility requested	Energy	Flexibility, DER activation
KPI_5	Congestion alleviation	Energy	Network Quality, Network Availability
KPI_6	Reduction in VRES curtailment	Energy	Energy, RES integration
KPI_7	DER hosting capacity increase	Energy	Energy, RES integration
KPI_8	Active power deviation from flexible units	Energy	Flexibility, DER activation
KPI_9	Activated flexibility compared to available flexibility	Energy	Flexibility, DER activation

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KPI ID	KPI name	KPI impact category	KPI aspect
KPI_10	Frequency of flexibility requests for ancillary services	Energy	Flexibility, DER activation
KPI_11	Cost of R&I solution VS grid alternative solution	Economic	Cost Savings, O&M Costs savings
KPI_12	PV performance ratio	Energy	RES Integration, Retailer Portfolio efficiency, Energy Efficiency, Energy Savings
KPI_13	Inverter Efficiency	Energy	Retailer Portfolio efficiency, Energy Efficiency, Energy Savings, RES Integrations
KPI_14	Distribution Equipment Maintenance Cost	Economic	Cost Savings, O&M Costs savings
KPI_15	Customers Experiencing Multiple Interruptions	Energy	Network Availability, Network Quality
KPI_16	Asset lifetime extension ratio	Energy	Network Availability, Network Quality
KPI_17	Percentage change of energy consumption for the consumer(a) and the portfolio (b)	Energy	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency
KPI_18	Generation forecasting accuracy	Energy	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency, Generation/Demand forecasting
KPI_19	Flexibility Forecasting Accuracy	Energy	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency, Generation/Demand forecasting
KPI_20	Demand forecasting accuracy	Energy	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency, Generation/Demand forecasting
KPI_21	Building energy consumption forecasting accuracy	Energy	Generation/Demand forecasting
KPI_22	GHG Emissions reduction	Environmental	Emissions
KPI_23	Calculation of building CO_2 emissions	Environmental	Emissions
KPI_24	Thermal comfort of occupants	Energy	Local Energy Communities efficiency
KPI_25	Self-consumption ratio (for the consumer/aggregator)	Energy	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency
KPI_26	Cost savings for consumers and other stakeholders	Economic	Cost Savings

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KPI ID	KPI name	KPI impact category	KPI aspect
KPI_27	Cost of purchasing energy	Economic	Cost Savings
KPI_28	Levelized cost of energy	Economic	Cost Savings
KPI_29	Costs savings due to renovation actions	Economic	Cost Savings, Urban Planning,
KPI_30	Energy Savings (storage driven/ RES driven)	Energy	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency
KPI_31	Energy rating of the building	Energy	Energy Performance
KPI_32	Building's total renewable generation	Energy	RES Integration, Energy Savings, Energy Performance
KPI_33	Energy savings on site for the building	Energy	Energy Savings, Energy Efficiency, Energy Performance
KPI_34	Flexibility for the grid and storage for the building	Energy	Energy Efficiency, Retailer Portfolio efficiency, Energy Performance
KPI_35	Comfort for the building	Energy	Energy Performance
KPI_36	Convenience for the building	Energy	Energy Performance
KPI_37	Health & wellbeing for the building	Energy	Energy Performance
KPI_38	Maintenance & fault prediction for the building	Energy	Energy Performance
KPI_39	Information to occupants for the building	Energy	Energy Performance
KPI_40	SRI of the building	Energy	Energy Performance
KPI_41	Time saving to select the required renovation actions	Economic	Urban Planning, Local Energy Communities efficiency
KPI_42	Flexibility on offer	Energy	Flexibility, DER activation
KPI_43	Flexibility on capacity	Energy	Flexibility, DER activation
KPI_44	Actual Flexibility Availability	Energy	Flexibility, DER activation
KPI_45	Flexibility Request	Energy	Flexibility, DER activation

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KPI ID	KPI name	KPI impact category	KPI aspect
KPI_46	Flexibility Activation	Energy	Flexibility, DER activation
KPI_47	Flexibility Override	Energy	Flexibility, DER activation
KPI_48	Actual Flexibility on Contract	Energy	Establishment of advanced Flexibility settlement and Remuneration Methods, Alternative (smart) contract types, Smart contract handling mechanisms
KPI_49	Flexibility Request on Contract	Energy	Establishment of advanced Flexibility settlement and Remuneration Methods, Alternative (smart) contract types, Smart contract handling mechanisms
KPI_50	Revenue on Contract	Energy	Establishment of advanced Flexibility settlement and Remuneration Methods, Alternative (smart) contract types, Smart contract handling mechanisms
KPI_51	Penalty on Contract	Energy	Establishment of advanced Flexibility settlement and Remuneration Methods, Alternative (smart) contract types, Smart contract handling mechanisms
KPI_52	Profit on Contract	Energy	Establishment of advanced Flexibility settlement and Remuneration Methods, Alternative (smart) contract types, Smart contract handling mechanisms
KPI_53	Payback Period	Economic	
KPI_54	Return on investment	Economic	

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4 SYNERGY Platform and Energy Apps Technical Validation

4.1 Technical Validation Approach

The SYNERGY technical evaluation framework intends to cover both software verification, i.e. the discovery and elimination of malfunctions and possible security issues, and validation, meaning the capability to fulfil the stakeholders' needs. The purpose of the evaluation framework from the technical perspective is to ensure that the "right" SYNERGY Big Data Platform & AI Marketplace (i.e. SYNERGY Platform, for brevity) and the "right" SYNERGY Energy Apps have been built in the "right" way, defining particular technical aspects and parameters that will be evaluated by the relevant electricity data value chain stakeholders. In essence, such a framework addresses both software verification and validation aspects in order to determine whether SYNERGY offers a platform of sufficient added value, with positive benefits to its intended users, allowing them to perform operations they could not do before, or allowing them to perform operations better or faster than they could before.

In order to guarantee the technical excellence, stability and reliability of the SYNERGY platform and energy apps, the following aspects are taken into consideration in the design of the SYNERGY "technical" evaluation framework:

- The User profiles that are mapped the identified stakeholder groups (e.g. DSOs, TSOs, Retailers, ESCOs, Aggregators, RES Operators, Facility Managers, City Authorities, etc.) acting as data asset providers and/or data asset consumers.
- The SYNERGY Business Scenarios, Business Requirements and Technical Requirements, as defined in the SYNERGY Deliverable D2.2.
- The need for a holistic evaluation approach, that dictates the evaluation of the technical robustness, the users' experience and the quality of the data assets.

The project's demonstrator partners have been engaged in the evaluation and feedback loops since the beginning of the development activities (across WP3-WP7), and have been exposed to preliminary versions of the SYNERGY platform and apps, allowing the respective technical partners to improve their components and the integrated platform, according to the continuous feedback that they have provided. Hence, in order to ensure the correct operation of the feedback cycle, the evaluation framework needs to become a structural aspect of the agile development lifecycle, where implementation and evaluation run in parallel. The benefits of this approach is that the speed, quality and efficiency of the development process is increased with the involvement and collaboration of all interested parties in the process. Structured and unstructured communication with stakeholders within and beyond the SYNERGY consortium will contribute in capturing the appropriate stakeholder's feedback and experience in the SYNERGY Platform and Energy Apps. At the end of each iteration, the results are evaluated by the demonstrators providing instant feedback that will drive the necessary adjustment and refinements in the next iteration.

4.2 Technical KPIs

Apart from the demonstrator scenarios that will be executed as presented in Section 5, monitoring a set of key performance indicators (KPIs) is critical to understand the overall operation of the SYNERGY Platform and Energy Apps from a technical perspective and the exploitation of data. While the ISO/IEC 25010:2011 [10] and ISO/IEC 25012:2008 [11] standards specify the evaluation criteria, the specific list of indicators to measure them is left to the adopters. For this reason, a set of specific KPIs that are tailored to the needs of SYNERGY project and the nature of the SYNERGY platform were defined and discussed. Table 9 lists the defined technical evaluation KPIs related to the product quality model. Such KPIs are measured by the SYNERGY technical partners. It needs to be noted that some indicators are marked as optional since their measurement might not be feasible in the context of the SYNERGY project due to the nature of the platform or the specific app, or might not provide added value in the evaluation process. Since compliance with the GDPR regulations must be also ensured, it is considered as prudent for the evaluation activities to also embrace high-level security performance indicators, to guarantee privacy respect and the minimization of risks of personal and private data leakages.

Table 9: Quantitative Technical Evaluation KPIs selected for the SYNERGY platform and apps

Sub-characteristics	Metric	Definition	Mandatory (Yes/N0)	Threshold Value
Functional suitability				
Functional completeness	Percentage of Technical Requirements completed, covering the functional requirements	[Completed Technical Requirements] / [Iteration Cycle of Technical Requirements] * 100%	Yes	>95%
Functional correctness	Percentage of Technical Requirements completed successfully	[Completed Technical Requirements without bugs] / [Iteration Cycle of Technical Requirements] * 100%	Yes	>90%
Functional appropriateness	Straightforward task accomplishment	Are tasks completed without the use of unnecessary steps? [Yes/No]	No	Yes
Performance efficiency				

Sub-characteristics	Metric	Definition	Mandatory (Yes/N0)	Threshold Value
Time behaviour	Average latency required for the accomplishment of specific (sub-)tasks	[Total response time] / [Number of requests]	Yes	Depending on the task
	Average Throughput during normal platform utilisation	[Total Number of Kilobytes] / [Total Time of Operation]	Yes	Depending on the task
Resource utilisation	Mean CPU Utilisation	[Σ[%CPU utilisation probes]] / [Number of probes]	Yes	<60%
	Mean memory usage	[Σ[RAM Megabytes used in each probe]] / [Number of probes]	Yes	<60%
	Maximum memory usage	Maximum % RAM Memory utilisation recorded	Yes	<90%
	Maximum processing power used	Maximum % CPU utilisation recorded	Yes	<90%
Capacity	Maximum database/ storage size	Total number of Kilobytes of files	Yes	>10 TB
Compatibility				
Co-existence	Ability to Co-Exist	Can the SYNERGY platform operate in shared environment? [Yes/No]	No	Yes
Interoperability	Exposure of APIs	Ability to expose information through well-defined APIs	Yes	Yes
	Ability to handle different datasets	Can the SYNERGY process and store datasets of different formats (i.e. csv, json, xml, other)?	Yes	Yes
	Ability to deliver different datasets	Can a user “download” from the SYNERGY platform processed data?	Yes	Yes
Operability				
Technical Learnability	% Coverage of features with learning documents	[Unique number of help documents mentioning a feature] / [Total number of features available] * 100%	Yes	100%
Ease of Use	Navigation menu availability	Is there a menu available with easy navigation? [Yes/No/Partially]	Yes	Yes
User error protection	% Coverage of input fields with error protection methods	[Number of error protected fields] / [Total number of critical input fields] * 100%	Yes	100%

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Sub-characteristics	Metric	Definition	Mandatory (Yes/N0)	Threshold Value
Technical Accessibility	WCAG 2.0 Conformance Level	[None/ A/ AA/ AAA]	Yes	A
	Cross-Platform Accessibility	Is the SYNERGY Platform accessible and operational through different platforms (e.g. Windows, Linux, MacOS)? [Yes/No/Partially]	Yes	Yes
	Cross-Browser Accessibility	Is the SYNERGY Platform accessible and operational through different browsers (e.g. Chrome/ Firefox / Edge)? [Yes/No/Partially]	Yes	Yes
	Cross-Device Accessibility	Is the SYNERGY Platform accessible and operational through different devices (i.e. PC/ Laptop)? [Yes/No/Partially]	Yes	Yes
Reliability				
Maturity	Simultaneous requests	Maximum number of simultaneous requests	Yes	>1000
Availability	% Monthly availability	[1-[Downtime in minutes] / [Total month minutes]] * 100%	Yes	>90%
	Success rate	[Number of correctly completed requests] / [Total numberof requests]	Yes	>95%
Fault tolerance	% of identified Software problems affecting the platform	[Critical Software Issues] / [Total number of Software faults detected] * 100%	Yes	<10%
	% of identified Hardware problems affecting the platform	[Critical Hardware Issues] / [Total number of Hardware faults detected] * 100%	Yes	<10%
Recoverability	Mean recovery time from Software problems	[Total recovering time from Software issues] / [Total number of Software issues in need of recovery]	Yes	<3h
	Mean recovery time from Hardware problems	[Total recovering time from Hardware issues] / [Total number of Hardware issues in need of recovery]	Yes	<24h
	Frequency of full backups to restore the operation	Number of backups taken on a weekly basis	Yes	1 per day for the SYNERGY

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Sub-characteristics	Metric	Definition	Mandatory (Yes/N0)	Threshold Value
	of the SYNERGY Platform / Energy Apps			Platform – 1 per week for the apps
Security				
Confidentiality	Unauthorised access to information	Number of recorded incidents	Yes	0 (None)
Integrity	Unauthorised tampering with information	Number of recorded incidents	Yes	0 (None)
Non-repudiation	Successful identity modification	Number of recorded incidents	Yes	0 (None)
	System failure to properly identify / authenticate user	Number of recorded incidents	Yes	0 (None)
	Level of User authenticity	Can you identify that a subject (organization or user) is the one it claims to be? [Yes/ No/ Partially]	Yes	Yes
Accountability	User actions traceability	Are usernames included in each activity log entry uniquely? [Yes/No]	Yes	Yes
	Percentage of actions logged	[Actions logged] / [Total number of system operations]	Yes	>95%
Maintainability				
Modularity	% of modularity	[Number of components that can operate individually] / [Total number of components] * 100%	Yes	>70%
Analysability	Level of analysability	Can the changes in the performance of the SYNERGY platform be efficiently evaluated after each upgrade? [Yes/No]	No	Yes
Modifiability	% of update effectiveness	[Number of updates performed without operational issues] / [Total number of updates] * 100%	Yes	>90%
Testability	Level of testing	Are tests able to probe the behaviour of the SYNERGY platform? [Code Coverage Indicator]	Yes	>80%
Portability				
Adaptability	Mean number of errors per hardware change/ upgrade	[Total number of errors recorded] / [Total number of hardware changes]	Yes	<10

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Sub-characteristics	Metric	Definition	Mandatory (Yes/N0)	Threshold Value
	Mean number of errors per software change/ update	[Total number of errors recorded] / [Total number of software changes]	Yes	<10

4.3 Data asset quality KPI

Data Assets are the key elements within the SYNERGY Platform. Since the eventually SYNERGY platform adoption is tightly related to the data assets whose management, sharing and analysis it facilitates, the data asset quality aspects as part of the product validation activities cannot be disregarded. The monitoring of the Data Assets on a constant basis is an indicated way to guarantee the efficiency and the usefulness of the SYNERGY Platform on its own and in conjunction with the different SYNERGY Energy Apps that are integrated with the Platform. Such monitoring of the Data Assets falls into the larger category of the data asset quality. Data quality refers to the development and implementation of activities that apply quality management techniques to data in order to ensure the data asset is fit to serve the specific needs of a particular project, such as the SYNERGY Platform.

Although the SYNERGY Platform offers functionalities for data quality improvement (in the Mapping and Cleaning steps), the data correctness, credibility, and completeness should be also evaluated and ensured by the respective data asset providers before the data are checked in. Once data assets become available to the SYNERGY Platform, the different data asset consumers should be able to evaluate them as a whole or individually, according to the metrics presented in Table 10. It needs to be clarified that only the confirmed "buyers" of data assets (that have an active data contract in the SYNERGY platform and may be either demo partners or technical partners) may provide an individual data asset evaluation on a voluntary basis.

Table 10: Data Asset Quality Evaluation Metrics selected for the SYNERGY Platform

Sub- characteristics	Metric	Definition	Mandatory (Yes/No)
Information Accuracy			
Correctness	Error-free data assets	To what degree do you find the data assets (datasets, models, results) provided reliable and errorless? [1-5]	Yes
Credibility	Acceptable ranges	To what degree do you find the data assets (datasets, results) provided containing values within the range of known or acceptable values? [1-5]	Yes
	Credibility of the data	To what degree do you find the	Yes

Sub- characteristics	Metric	Definition	Mandatory (Yes/No)
	asset provider	originating source of the provided data asset (experts or organisation of a country, field, or industry) credible? [1-5]	
Currentness	Update of the data	To what degree have you experienced that the data are up-to-date or regularly updated? [1- 5]	Yes
Traceability	Data source provenance	To what degree do you find that the originating source of the provided data asset is easily identified? [1-5]	No
Information Accessibility			
Accessibility	Data access	To what degree do you find to which the provided data can be accessed from different systems? [1-5]	Yes
	Data asset policy	To what degree do you find that access control should be enforced to the provided data asset depending on the assigned access level (private, public)? [1-5]	No
Information Appropriateness			
Completeness	Context of use fitness	To what degree do you find that the provided data assets contain information relevant to their described context of use? [1-5]	Yes
	Missing information expected	To what degree do you find that the provided datasets are complete and with no missing entries or missing values? [1-5]	No
Understandability	Definition/ Documentation	To what degree do you find that the provided data assets are accompanied by appropriate metadata? [1-5]	Yes
Consistency	Duplicate instances	To what degree do you find that the provided datasets are free of repeated instances of the same property that is not allowed [1-5]	No
Representational Adequacy	Adequate visualization features	To what degree do you find that the SYNERGY platform offers the suitable visualisation options for the provided analytics results depending on the intended context of use? [1-5]	Yes
	Normative data definition	To what degree do you find that the provided data (content, format, etc.) are clear and understandable? [1-5]	Yes
Value Added	Benefit for the user	To what degree do you find that the provided data assets are beneficial and provide added value to the user? [1-5]	Yes

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4.4 User experience / Perception KPIs

When it comes to the user experience and perception of software, Business Validation depends mostly on meeting criteria set by users, which will help them to identify and measure the impact and the usefulness of the SYNERGY platform/energy apps in their everyday operations. For each demonstrator and "electricity data value chain stakeholder, a different set of documents will be produced, to gather the questions asked in a standardized form and capture the experience gained from the SYNERGY platform and the relevant energy apps.

Table 11 presents the quantitative and qualitative evaluation metrics which correspond to the evaluation of the SYNERGY platform and apps operation phase by the demonstrators. In general, many of the key performance indicators (KPIs) that are adopted refer to the Quality in Use model and the usability aspects of the ISO/IEC 25010:2011 and are measured in a qualitative manner, either by measuring AS-IS and TO-BE values, or in case of more qualitative answers, by using a 1-5 scale.

It needs to be noted that for the case of the SYNERGY Platform, the user experience can be also evaluated by the technical partners that have used it to provide pre-trained analytics solutions (in WP4) or energy apps (in WP5-WP7).

Table 11: User Experience/Acceptance Evaluation KPIs (applied both the SYNERGY Platform and the energy apps)

Sub-characteristics	Metric	Definition	Mandatory (YES/NO)
Business Value			
Clarity	Clarity level	How clear was it for you what the SYNERGY platform/energy app is about? [Scale 1 (Little) -5 (Very)]	Yes
Added Value	Added value level	How much added value do you feel that the SYNERGY platform/energy app provides to your operations while using it? [Scale 1 (Low) -5 (High)]	Yes
Need Importance Level	Need importance level	How important is for you the need that the SYNERGY platform/energy app covers for you? [Scale 1 (Little) -5 (Very)]	Yes
Need Coverage	Need coverage level	To what degree does the SYNERGY platform/energy app covers your needs? [Scale 1 (Low) -5 (High)]	Yes
Innovation	Innovation level	How innovative do you find the idea of the SYNERGY platform/energy app? [Scale 1 (Little) - 5 (Very)]	Yes
Intention to use	Intention level	To what extent do you intend to use the SYNERGY platform/energy app? [Scale 1 (Low) - 5 (High)]	No
Virality	Virality level	How probable is it for you to recommend the SYNERGY platform/energy app to other stakeholders in your network? [Scale 1 (Low) -5 (High)]	Yes

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Sub-characteristics	Metric	Definition	Mandatory (YES/NO)
Effectiveness			
Effectiveness	Effectiveness level	Is the SYNERGY platform/energy app enabling you to accurately achieve your goals for data sharing and analytics? [Scale 1 (Low) -5 (High)]	Yes
Efficiency			
Efficiency	Efficiency level	Is the SYNERGY platform/energy app efficiently fulfilling its intended purpose? [Scale 1 (Low) - 5 (High)]	Yes
Satisfaction			
Usefulness	Usefulness level	Do you find the SYNERGY platform/energy app useful? [Scale 1 (Low) -5 (High)]	Yes
Trust	Trust level	Do you trust the SYNERGY platform/energy app and its provided functionalities? [Scale 1 (Low) -5 (High)]	Yes
Pleasure	Pleasure level	Does the SYNERGY platform/energy app please you when you use it? [Scale 1 (Low) -5 (High)]	Yes
Comfort	Comfort level	Do you feel that the SYNERGY platform/energy app provides a comfortable/user-friendly user interface and workflows? [Scale 1 (Low) -5 (High)]	Yes
Freedom from risk			
Economic damage risk	Level of economic damage risk	How sure are you that SYNERGY protects you from exposing you on economic damage? [Scale 1 (Low) -5 (High)]	Yes
Privacy harm risk	Level of data privacy damage risk	How sure are you that SYNERGY is on protecting your data privacy? [Scale 1 (Low) -5 (High)]	Yes
Usability			
Learnability	Learnability level	How easy it was for you to learn how to use the SYNERGY platform/energy app? [Scale 1 (Not) -5 (Very)]	Yes
Flexibility	Flexibility level	How much do you believe the SYNERGY platform/energy app can be used for other applications than the demonstrator cases? [Scale 1 (Low) -5 (High)]	Yes
Content Conformity	Content quality	How useful do you find the data and the applications found in the SYNERGY platform in terms of quality? [Scale 1 (Little) -5 (Very)]	Yes
	Content quantity	How satisfied are you from the quantity of the data assets and the analytics models found in the SYNERGY platform? [Scale 1 (Little)-5 (Very)]	Yes

In addition, it is important to identify the exact customer segments in the electricity data value chain that are really interested in the SYNERGY platform. To this direction, a correlation of the users accessing the platform with their characteristics (gathered through dedicated questionnaires) can help the project identify what are the target segments of the platform. In alignment with TAM2 that puts

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emphasis on the user context during the evaluation process, the results should be examined for correlation based on the following user characteristics:

- Experience: how many years the user has been doing this job, or using similar "data" systems
- Image: how influential the user is considered in general and within his/her organization
- Job Relevance: the relevance of the user's job with the SYNERGY platform
- Output Quality: how the user perceived the quality of the output in total, even if he/she is interested in the platform or not
- Result Demonstrability: if the user is willing to show to someone the results obtained through the SYNERGY platform

Although running behavioural tests, like those proposed in the quality in use and data quality models, is complex, SYNERGY shall adopt the following workflow for controlled tests:

- Users should enter the SYNERGY Platform/energy app with only a minimum of information about they can expect or do, but they should have at their disposal appropriate training material/documentation.
- Users are left free to explore the SYNERGY Platform/energy app, trying to devise how to accomplish the requested test cases or fulfil a need they have (e.g. to find data or acquire data and run an analysis in the SYNERGY Platform).
- Users should be given also goals and tasks, outside the specific user stories, to see how they behave (e.g.: "If you need to share the results of an analysis, how would you do it?").
- Every failure to complete a task should be documented, and analysed with specific follow-up questions. In case of malfunctions, bug reports should be collected with collaboration with the users (like screenshot capturing). Such a process has been already in place for the SYNERGY Platform in github and slack since M18 (as reported in the SYNERGY Deliverable D3.4).
- Users profiles should be carefully collected.
- The users should fill in an appropriate questionnaire built based on the metrics of Table 11 (that may be further detailed depending on the type of the user, e.g. data provider or data consumer), collecting data from the user.
- The SYNERGY consortium should schedule a short interview with each user to discuss the user experience in the SYNERGY Platform/energy app.

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Such evaluation information will be duly gathered in the framework of Task T8.4 "Pilot Baselining, roll-out and demonstration" and T8.5 "Socio-economic, environmental and technological impact assessment" and shall be presented in the SYNERGY Deliverables D8.5 (M33) and D8.6 (M42).

5 Demo Specific Validation Scenarios

In this section, the different Validation Scenarios that derive from each Demo Case are thoroughly described. Validation Scenarios refer to the specific steps that each Demo Partner will take in order to measure and verify the performance of each Demo Case. Each Validation Scenario is defined by a small description, its objectives, the involved stakeholders, its Use Cases, the data assets, energy applications, hardware and data analytics that it uses, its workflow and the KPIs that will be used for measurement and verification. The typical workflow of each Validation Scenario is the following: during the preliminary phase, the necessary data and service (service is referring to the energy applications, hardware and data analytics of the SYNERGY Platform) pre-processing takes place which is analytically described. Then, the triggering event which activates the Validation Scenario is defined. This is the activation phase. Afterwards, the main phase follows, where the main tasks of the services that are involved in the Validation Scenario are executed in order to process, exchange and produce data assets. Finally, the results of the Validations Scenario are presented.

5.1 Evaluation in Greek Demo

5.1.1 Demo Case 1: Innovative Flexibility-based Network Management

5.1.1.1 Validation Scenario

Description

Demo case 1, Innovative Flexibility-based Network Management, focuses on providing an analysis on real consumption/generation data for short and mid-term, as well as forecasts exploited by both DSO and TSO, in order to identify emerging network needs and necessary flexibility amounts, satisfied by retailers and aggregators’ relevant strategies on their clientele.

A proposed flexibility schedule will be the outcome of this analysis, aiming at increasing network resilience and operational efficiency, maximizing RES integration, minimizing power losses, increasing power quality and safeguarding network availability against anticipated congestions, imbalances, frequency/ voltage violations.

All four major actors of the Greek Energy market are involved, HEDNO acting as DSO, IPTO as TSO, EPA as retailer and VERD as aggregator/ESCO.

In order to achieve this demo case, all the relevant data need to be communicated, through the SYNERGY platform, to the Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling application so as to analyse them and propose the most optimal flexibility schedule according to the network needs.

The following validation scenarios can be tested in order to make sure that the outcome is as expected:

- Validation Scenario 1: Data transmitted correctly to SYNERGY Platform
- Validation Scenario 2: Data received correctly from Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling application through the SYNERGY Platform.
- Validation Scenario 3: Testing with multiple flexibility scenarios.
- Validation Scenario 4: Flexibility schedule pairs flexibility availability and demand.

Objectives

Demo case Objectives:

- Target 1: Improvement in accuracy of demand and generation forecasts (in the short- and mid-term) for the TSO and DSO (effective market operation).
- Target 2: Network operation efficiency in conjunction with improved RES exploitation
- Target 3: Increased cooperation among Retailers and Network Operators managing flexibility needs and provision in mutually beneficial approach.
- Target 4: Flexibility strategies and advanced load management for the retailers with increased customer engagement.

Objective/goals/targets of the validation scenarios:

- Objective 1: Data is successfully and accurately uploaded from all demo partners to the SYNERGY platform.
- Objective 2: Data is successfully and accurately transmitted to Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling application.
- Objective 3: Flexibility scenarios cover different temporal, spatial and quantitative conditions.
- Objective 4: Proposed flexibility schedule efficiently and sufficiently matches the flexibility availability and demand.

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

Stakeholders

Stakeholders involved and their role in the Validation Scenarios (VSs) are:

- HEDNO: DSO, Data Owner, Data Provider, Data Consumer, Data broker and Data Scientists
- IPTO: TSO, Data Owner, Data Provider and Data consumer
- EPA: Retailer, Data Owner, Data Provider and Data Consumer
- VERD: Aggregator/ESCO, Data Owner, Data Provider, Data Consumer and Data broker
- ICCS: Data Management and Services provider

Use cases[1]

- UC_5_3: Flexibility Based Network Manager
- UC_5_4: DSO-TSO Common Operational Scheduler

Available Data Assets

The data assets that will be used to develop DC 1 are introduced in Table 12.

Table 12: Available Data Assets for DC1

Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform
GR_HEDNO_1	Metering data from smart meters and AMI of MV and LV customers	HEDNO	Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling	Available in 1st Iteration
GR_HEDNO_2	Metering data from normal meters of LV customers	HEDNO	Flexibility-Based Network Manager and DSO-TSO Common	Available in 1st Iteration

[1] It should be noted that WP3 and WP4 use cases are inherent and preconditions for the demo validation scenarios, therefore they are not explicitly mentioned here. The same situation applies to all the following use cases mentioned in the rest of the chapter.

Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform
			Operational Scheduling	
GR_HEDNO_3	SCADA/DMS events and SCADA measurements of P, Q, V, I for HV/MV substations	HEDNO	Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling	Available in 1st Iteration
GR_HEDNO_4	Flexibility requirements at DSO level	HEDNO	Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling	Available in 1st Iteration
GR_HEDNO_5	RES production measurements for connections in Distribution Network	HEDNO	Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling	Available in 1st Iteration
GR_HEDNO_6	MV/LV Network Topology and Equipment Status from GIS	HEDNO	Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling	Available in 1st Iteration
GR_IPTO_1	Measurements of HV substation	IPTO	Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling	Available in 1st Iteration
GR_IPTO_3	Spatial data regarding the location of transmission system components	IPTO	Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling	Available in 1st Iteration

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Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform
GR_IPTO_4	Aggregated generation forecast for the Greek transmission system	IPTO	Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling	Available in 1st Iteration
GR_EPA_1	Electricity consumption of EPA's customer portfolio	EPA	Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling	Available in 1st Iteration
GR_EPA_2	SMP and ex-post SMP values	EPA	Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling	Available in 1st Iteration
GR_EPA_3	Electricity prices and coefficients of regulated retail costs	EPA	Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling	Available in 1st Iteration
GR_EPA_5	Consumption of EPA's MV customers	EPA	Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling	Available in 1st Iteration
GR_EPA_6	Consumption of EPA's LV customers	EPA	Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling	Available in 1st Iteration
GR_VERD_1	Energy imported from the Grid (kWh)	VERD	Flexibility-Based Network Manager and DSO-TSO Common	Available in 1st Iteration

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform
			Operational Scheduling	
GR_VERD_2	Energy exported to the Grid (kWh)	VERD	Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling	Available in 1st Iteration
GR_VERD_3	Energy produced (kWh)	VERD	Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling	Available in 1st Iteration
GR_VERD_4	Consumption (KWh)	VERD	Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling	Available in 1st Iteration

Energy applications

The energy applications that will be used to develop DC1 are introduced in Table 13.

Table 13: Energy applications tested within DC1

Energy app name	Components	Input data assets (IDA)	Output data assets (ODA)
Flexibility-Based Network Manager and DSO-TSO Common Operational	Flexibility Network Manager Component: A tool that allows the DSO to operate the distribution grid in an optimal manner, using the flexibility provided by DERs to solve forecasted problems, to take advantage of the grid flexibility and operate under severe circumstances - ICCS	IDA 1 – HEDNO (GR_HEDNO_1, 2, 3, 4, 5, 6) IDA 2 – IPTO (GR_IPTO_1, 2, 3, 4)	ODA 1 – HEDNO (GR_HEDNO_DN_1, 2, 6, Aggregated flexibility potential & deficit per substation, Margins to increase/decrease load per feeder/substation. List of conflicts between requests, Short term TSO scheduling,

Energy app name	Components	Input data assets (IDA)	Output data assets (ODA)
Schedulin g			Priority list of flexibility requests) ODA 2 – IPTO (GR_IPTO_DN_1, 2, 5, Aggregated flexibility potential & deficit per substation, List of conflicts between request, Short term DSO scheduling, Priority list of flexibility requests

Data analytics

The analytics that are expected to be used for the implementation of DC1 are introduced in Table 14. Data analytics are executed in the SYNERGY Platform, with the exception of simulation algorithms that involve power flow calculations and are executed offline. Those cases are mentioned below in the description as 'executed offline'.

Table 14: Available Data Assets for DC1

Data Analytics name	Description	Input data assets (IDA)	Output data assets (ODA)
Prediction of energy demand in short-term	Learning models for forecasting the total energy demand at different levels (e.g. grid, district portfolio etc.) ICCS, ETRA, UCY, UBI	Time Series and Energy demand data	Energy demand Prediction
Prediction of energy generation in short-term	Learning models for forecasting the total energy generation at different levels (e.g. grid, district portfolio etc.) ICCS, CIRCE, COBRA	Time Series and Energy generation data	Energy generation prediction

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

Data Analytics name	Description	Input data assets (IDA)	Output data assets (ODA)
Prediction of generation/demand/storage flexibility at DER level	Analytics for forecasting flexibility generation/demand/storage at DER level. ICCS, SUITE5	DER level weather and generation/demand/storage data	Available flexibility at DER level
Aggregate flexibility estimates received from portfolio analytics engine	Aggregate at substation level the flexibility estimates received from the SYNERGY platform ICCS	Time series of flexibility estimation	Aggregation of flexibility in substation and feeder level
Identification of margins/requirements for flexibility	Runs network operational studies to extract network margins and flexibility requirements. To be executed offline. ICCS	Network capacity limits and Flexibility resources limitations	Margins to increase/decrease load in each feeder
Calculation of flexibility deficit periods	Identifies deficits on flexibility requirements during the scheduling period. To be executed offline. ICCS	Resulting Flexibility scheduling and Time series of estimated flexibility	Time series of flexibility deficit
Identification of flexibility products in need	Identifies flexibility requirements of network operators and describes them in terms of services. To be executed offline. ICCS	Knowledge of market set up	Corresponding flexibility requirements to available market products
Identification of conflicts in flexibility requirements between operators	Compares flexibility requirements time series from DSO and TSO and identifies conflicts in flexibility needs. To be executed offline.	Flexibility requests	List of conflicts between requests

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Data Analytics name	Description	Input data assets (IDA)	Output data assets (ODA)
	ICCS		
Short term DSO scheduling	Performs optimal scheduling algorithms for DSO to decide scheduling for the next hours. To be executed offline. ICCS	Forecasts for short-term demand and DER/RES generation	Upward and downward flexibility scheduling Power deviation Short-term scheduling
Short term TSO scheduling	Performs optimal scheduling algorithms for TSO to decide scheduling for the next hours. To be executed offline. ICCS	Forecasts for short-term demand and DER/RES generation	Upward and downward flexibility scheduling Power deviation Day ahead/intraday/balancing scheduling
Prioritization of requests	Flexibility requests from DSO and TSO are prioritized according to the agreed coordination scheme. To be executed offline. ICCS	Coordination agreement and rules	Priority list of flexibility requests

<u>Hardware Components</u>

The hardware components used for the implementation of DC1 are listed in **Error! Reference source not found.**

Table 15: Available Data Assets for DC1

Hardware component id	Description	Input data assets (IDA)	Output data assets (ODA)
HW 1	AMI System – HEDNO	-	Metering data from smart meters and AMI of MV customers and large volume LV customers .csv

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Hardware component id	Description	Input data assets (IDA)	Output data assets (ODA)
HW 2	SCADA System – HEDNO	-	SCADA/DMS events and SCADA measurements of P, Q, V, I for HV/MV substations .csv
HW 3	GIS System – HEDNO	-	MV/LV Network Topology and Equipment Status from GIS .json / .dwg
HW 4	SCADA System – IPTO	-	SCADA measurements of P, Q, V, I per substation .csv
HW 5	EMS System – IPTO	-	Energy measurements per substation .csv
HW 6	GIS System – IPTO	-	Spatial data regarding the location of transmission system components .png/.pdf/.jpeg
HW 7	Operations Database – EPA	-	Metering data of MV/LV customers .csv/.xlsx
HW 8	Billing Database – EPA	-	Electricity prices and coefficients of regulated retail costs .xlsx
HW 9	CRM Database – EPA	-	Data regarding customer installations .xlsx
HW 10	PV System – VERD	-	RES installation Data (energy imported/exported etc.) .csv

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Hardware component id	Description	Input data assets (IDA)	Output data assets (ODA)
HW 11	Storage System (Inverter) – VERD	-	Storage installation Data (Batteries SoC, Power, charging state etc.) .csv
HW 12	Smart Devices – VERD	-	Data from IoT devices (energy, humidity, temperature, occupancy etc.) .csv/.xlsx

Workflow

The following sequential diagram and flow chart depict how the Demo Case will be implemented:

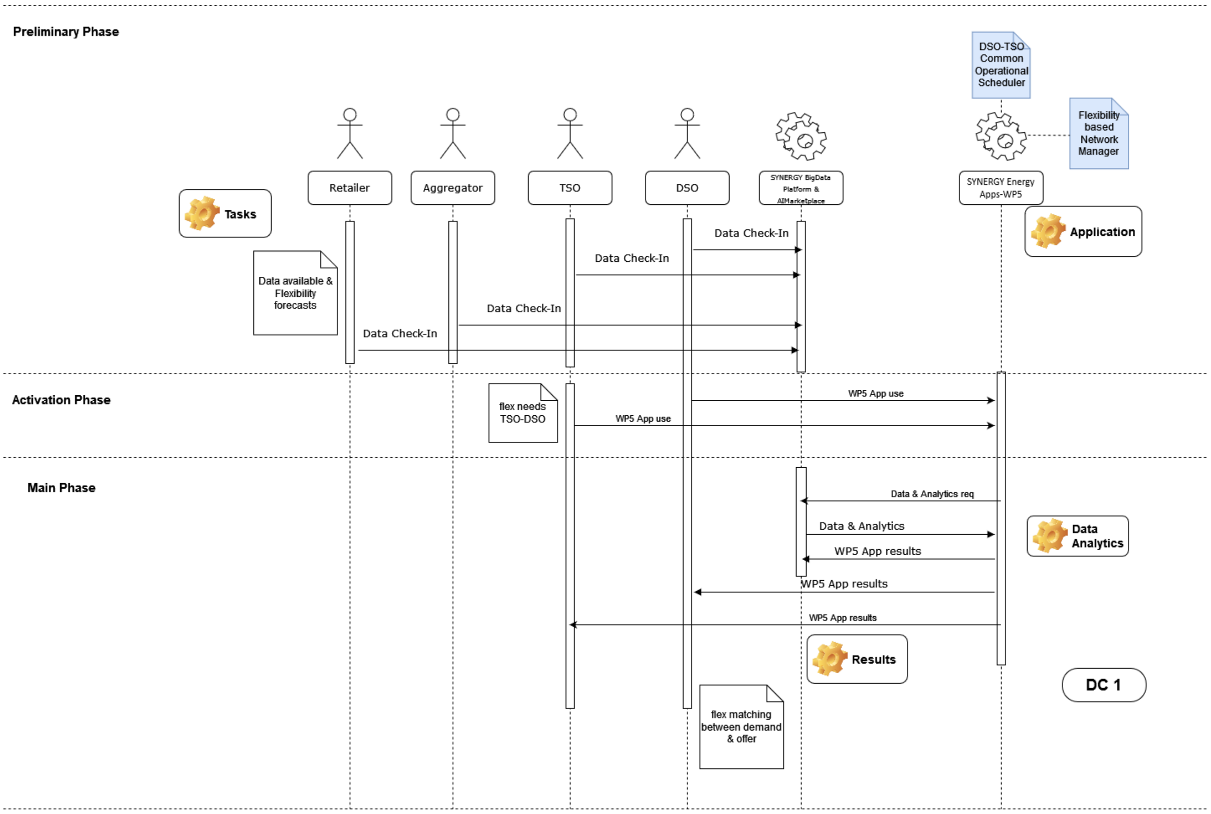

Figure 9: DC1 sequential diagram

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

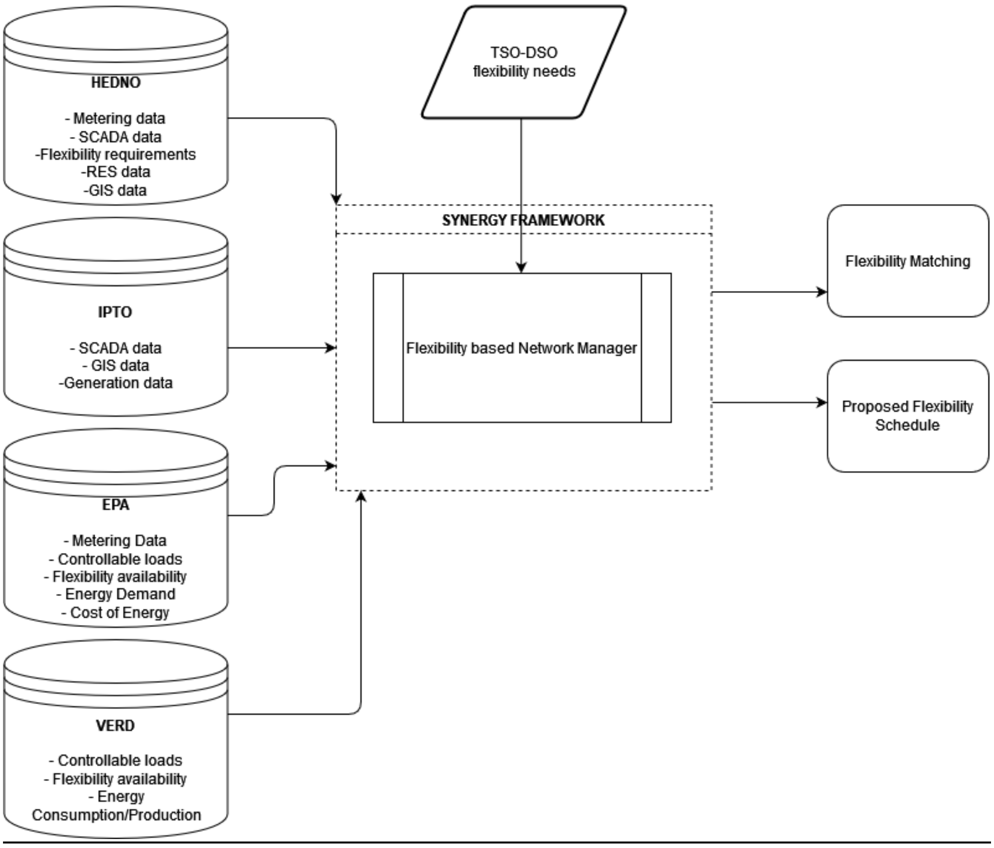

Figure 10: DC1 workflow flowchart

The Demo Case will be validated as follows, during both Demo runs:

First Demo run:

Validation Scenario 1: Data transmitted correctly to SYNERGY Platform
Preliminary phase: describe preparation processes
All data is pre-processed by the providing partner.
Activation phase: define the triggering event
Data is submitted to the SYNERGY platform.
Main phase: describe main processes of validation scenario
Data is successfully uploaded and accepted/processed by the Data Ingestion Services of the SYNERGY platform.
Data assets are checked to verify that they have been uploaded correctly.
Results: Uploaded data assets are processed and available in the SYNERGY platform.

Validation Scenario 2: Data received correctly from Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling application through SYNERGY Platform.
Preliminary phase: describe preparation processes
All data is processed and available in the platform.
Activation phase: define the triggering event
Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling application is invoked, through SYNERGY Platform.
Main phase: describe main processes of validation scenario

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

Check if Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling application is able to find and load the correct data assets when they are invoked **Results:** Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling application should contain the needed data to run.

First and Second Demo run:

Validation Scenario 3: Testing with multiple flexibility scenarios.
Preliminary phase: describe preparation processes
Different data sets are available on the SYNERGY platform that cover different possible flexibility scenarios.
Activation phase: define the triggering event
Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling application is invoked, through the SYNERGY Platform.
Main phase: describe main processes of validation scenario
Check if Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling application is able to process and generate an outcome in different test scenarios. **Results:** Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling application should work in all scenarios tested.

Validation Scenario 4: Flexibility schedule pairs flexibility availability and demand.
Preliminary phase: describe preparation processes
A request is made by a DSO or TSO for available Flexibility due to flexibility needs. **Activation phase:** define the triggering event
Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling application is invoked, through SYNERGY Platform.
Main phase: describe main processes of validation scenario
The Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling application is able to process data and try to match the requests with the available flexibility. **Results:** Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling application successfully matches available flexibility with the requested.

5.1.1.2 Impact KPIs

The KPIs that will be assessed in this demo case are:

- Volume of flexibility requested
- Flexibility forecasting Accuracy
- Flexibility on offer
- Flexibility on capacity
- Actual Flexibility Availability
- Flexibility Request

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5.1.1.3 Preliminary Evaluation Plan

The preliminary evaluation plan, during the first demo run, will consist mainly of making sure that all the applications and components developed, along with the corresponding analytics and algorithms, are working as intended and can provide reliable and feasible results. More specifically, the forecasting flexibility, energy and load KPIs should be verified that they have low mean absolute error, in order to ensure the correct training of the corresponding analytics. Furthermore, the data needed and uploaded to the SYNERGY platform must be adequately provided and validated in order to ensure that the necessary requirements for the execution of the demo case are met.

After these pre-conditions are met, during the second demo run, the developed applications will be evaluated as a whole, in order to ensure that all of SYNERGY's goals are met successfully. For this demo case, the presence of demand and available flexibility and the ensuing pairing will be evaluated, so that the delivered outcome is feasible.

5.1.2 Demo Case 2: Common Operational Scheduling of power grids (D&T) for TSOs and DSOs

5.1.2.1 Validation Scenario

Description

Demo case 2, Common Operational Scheduling of power grids (T&D) for TSOs and DSOs, HEDNO & IPTO will validate a collaborative tool enabling them to exchange info on critical grid events, identify, prioritize and match available flexibility sources (and clusters of them).

Through an appropriately configured toolbox, providing common interfaces to both actors, HEDNO and IPTO will (i) gain increased visibility over available flexibility sources and proper clusters of them, based on information shared by EPA and VERD, (ii) collaboratively rank their flexibility requirements to enable the highlighting of critical operational events at both levels of electricity grid operation and allow for their criticality prioritization and (iii) perform matching of available flexibility resources towards ensuring the smooth operation of power grids under evolving conditions through optimal operational scheduling and evaluation of offered flexibility capacity for potential capability exploitation.

A common interface for DSOs and TSOs will be created for mutual communication during critical events and for joint assessment towards flexibility prioritization and activation, aiming at enabling collaborative and knowledge-based conflict resolution and proactively raise potential flexibility conflicts and facilitate alternative scheduling.

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

The following validation scenarios can be tested in order to make sure that the outcome is as expected:

- Validation Scenario 1: Data transmitted correctly to SYNERGY Platform
- Validation Scenario 2: Data received correctly from Flexibility based network management and DSO-TSO Common Operational Scheduling Application.
- Validation Scenario 3: Testing with multiple critical grid events requiring flexibility prioritization.
- Validation Scenario 4: Operational schedule prioritizes flexibility needs of DSO and TSO.
- Validation Scenario 5: Existing contracts/SLAs between network operators and flexibility providers cover the proposed scheduling.

Objectives

Demo case Objectives:

- Target 1: Flexibility mechanisms for efficient transmission and distribution network management.
- Target 2: Increased visibility over available flexibility sources and proper clusters of them, based on information shared by EPA and VERD.
- Target 3: Common operation TSO/DSO platform in order to manage flexibility and services such as frequency response, voltage regulation, and congestion management

Objective/goals/targets of the validation scenarios:

- Objective 1: Data is successfully and accurately uploaded from all demo partners to SYNERGY platform.
- Objective 2: Data is successfully and accurately transmitted to Flexibility-Based Network Management and DSO-TSO Common Operational Scheduling application.
- Objective 3: Successful implementation of different flexibility needs.
- Objective 4: Proposed schedule efficiently and sufficiently satisfies the flexibility needs of DSO and TSO.
- Objectives 5: Smooth potential implementation of proposed operational schedule.

Stakeholders

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

Stakeholders involved are:

- HEDNO: DSO, Data Owner, Data Provider, Data consumer, Data broker and Data Scientists.
- IPTO: TSO, Data Owner, Data Provider and Data consumer
- EPA: Retailer, Data Owner, Data Provider and Data consumer
- VERD: Aggregator/ESCO, Data consumer and Data broker.

Use cases

- UC_5_3: Flexibility Based Network Manager
- UC_5_4: DSO-TSO Common Operational Scheduler

Available Data Assets

The data assets that will be used to develop DC 2 are introduced in Table 16.

Table 16: Available Data Assets for DC2

Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform
GR_HEDNO_1	AMI & Smart Metering Data	HEDNO	Flexibility Network Management and DSO-TSO common operational scheduling Application	Available in 1st Iteration
GR_HEDNO_2	Metering data from normal meters of LV customers	HEDNO	Flexibility Network Management and DSO-TSO common operational scheduling Application	Available in 1st Iteration
GR_HEDNO_3	SCADA/DMS events and SCADA measurements of P, Q, V, I for HV/MV substations	HEDNO	Flexibility Network Management and DSO-TSO common operational scheduling Application	Available in 1st Iteration

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GR_HEDNO_4	Flexibility requirements at DSO level	HEDNO	Flexibility Network Management and DSO-TSO common operational scheduling Application	Available in 1st Iteration
GR_HEDNO_5	RES production measurements for connections in Distribution Network	HEDNO	Flexibility Network Management and DSO-TSO common operational scheduling Application	Available in 1st Iteration
GR_HEDNO_6	MV/LV Network Topology and Equipment Status from GIS	HEDNO	Flexibility Network Management and DSO-TSO common operational scheduling Application	Available in 1st Iteration
GR_IPTO_1	Measurements of HV substation	IPTO	Flexibility Network Management and DSO-TSO common operational scheduling Application	Available in 1st Iteration
GR_IPTO_2	Data about short- and mid-term flexibility requirements based on the needs of the transmission system operator	IPTO	Flexibility Network Management and DSO-TSO common operational scheduling Application	Available in 1st Iteration
GR_IPTO_4	Aggregated generation forecast for the Greek transmission system	IPTO	Flexibility Network Management and DSO-TSO common operational scheduling Application	Available in 1st Iteration
GR_EPA_1	Electricity consumption of EPA's customer portfolio	EPA	Flexibility Network Management and DSO-TSO common operational scheduling Application	Available in 1st Iteration

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

GR_EPA_2	SMP and ex-post SMP values	EPA	Flexibility Network Management and DSO-TSO common operational scheduling Application	Available in 1st Iteration
GR_EPA_3	Electricity prices and coefficients of regulated retail costs	EPA	Flexibility Network Management and DSO-TSO common operational scheduling Application	Available in 1st Iteration
GR_EPA_5	Consumption of EPA's MV customers	EPA	Flexibility Network Management and DSO-TSO common operational scheduling Application	Available in 1st Iteration
GR_EPA_6	Consumption of EPA's LV customers	EPA	Flexibility Network Management and DSO-TSO common operational scheduling Application	Available in 1st Iteration

Energy applications

The energy applications that will be used to develop DC2 are introduced in **Error! Reference source not found.**.

Table 17: Energy applications for DC2

Energy app name	Components	Input data assets (IDA)	Output data assets (ODA)
Flexibility Network Manager and DSO-TSO Common Operation al Schedulin g	Flexibility Network Manager Component: A tool that allows the DSO to operate the distribution grid in an optimal	IDA 1 – HEDNO (GR_HEDNO_1, 2, 3, 4, 5, 6) IDA 2 – IPTO (GR_IPTO_1, 3, 4)	ODA 1 – HEDNO (GR_HEDNO_DN_1, 2, 6, Aggregated flexibility potential & deficit per substation, Margins to

	manner, using the flexibility provided by DERs to solve forecasted problems, to take advantage of the grid flexibility and operate under severe circumstances - ICCS		increase/decrease load per feeder/substation) ODA 2 – IPTO (GR_IPTO_DN_1, 2, 5, Aggregated flexibility potential & deficit per substation)
Flexibility Network Manager and DSO-TSO Common Operational Scheduling	DSO-TSO Common Operational scheduling Component: A tool for the DSO and the TSO in order to facilitate common operational scheduling, considering the flexibility requirement for both actors for congestion management needs, balancing needs and other relevant ancillary services.	IDA 1 – HEDNO (GR_HEDNO_1, 2, 3, 4, 5, 6) IDA 2 – IPTO (GR_IPTO_1, 2, 4)	ODA 1 – HEDNO (GR_HEDNO_DN_1, 2, 6, List of conflicts between requests, Short term TSO scheduling, Priority list of flexibility requests) ODA 2 – IPTO (GR_IPTO_DN_1, 2, 5, List of conflicts between request, Short term DSO scheduling, Priority list of flexibility requests)

Data analytics

The analytics that are expected to be used in DC2 are introduced in Table 18. Data analytics are executed in the SYNERGY Platform, with the exception of simulation algorithms that involve power flow calculations and are executed offline. Those cases are mentioned below in the description as ‘executed offline’.

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Table 18: Data analytics for DC2

Data Analytics name	Algorithm	Input data assets (IDA)	Output data assets (ODA)
Prediction of energy demand in short-term	Learning models for forecasting the total energy demand at different levels (e.g. grid, district portfolio etc.) ICCS, ETRA, UCY, UBI	Time Series and Energy demand data	Energy demand Prediction
Prediction of energy generation in short-term	Learning models for forecasting the total energy generation at different levels (e.g. grid, district portfolio etc.) ICCS, CIRCE, COBRA	Time Series and Energy generation data	Energy generation prediction
Prediction of generation/demand/storage flexibility at DER level	Analytics for forecasting flexibility generation/demand/storage at DER level. ICCS, SUITE5	DER level weather and generation/demand/storage data	Available flexibility at DER level
Aggregate flexibility estimates received from portfolio analytics engine	Aggregate at substation level the flexibility estimates received from the SYNERGY platform ICCS	Time series of flexibility estimation	Aggregation of flexibility in substation and feeder level
Identification of margins/requirements for flexibility	Runs network operational studies to extract network margins and flexibility requirements. To be executed offline. ICCS	Network capacity limits and Flexibility resources limitations	Margins to increase/decrease load in each feeder
Calculation of flexibility	Identifies deficits on flexibility requirements during the scheduling	Resulting Flexibility scheduling and Time series of estimated flexibility	Time series of flexibility deficit

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

deficit periods	period. To be executed offline. ICCS		
Identification of flexibility products in need	Identifies flexibility requirements of network operators and describes them in terms of services. To be executed offline. ICCS	Knowledge of market set up	Corresponding flexibility requirements to available market products
Identification of conflicts in flexibility requirements between operators	Compares flexibility requirements time series from DSO and TSO and identifies conflicts in flexibility needs. To be executed offline. ICCS	Flexibility requests	List of conflicts between requests
Short term DSO scheduling	Performs optimal scheduling algorithms for DSO to decide scheduling for the next hours. To be executed offline. ICCS	Forecasts for short-term demand and DER/RES generation	Upward and downward flexibility scheduling Power deviation Short-term scheduling
Short term TSO scheduling	Performs optimal scheduling algorithms for TSO to decide scheduling for the next hours. To be executed offline. ICCS	Forecasts for short-term demand and DER/RES generation	Upward and downward flexibility scheduling Power deviation Day ahead/intraday/balancing scheduling
Prioritization of requests	Flexibility requests from DSO and TSO are prioritized according to the agreed coordination scheme. To be executed offline. ICCS	Coordination agreement and rules	Priority list of flexibility requests

Hardware Components

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

The hardware components used for the implementation of DC2 are listed in **Error! Reference source not found.**.

Table 19: Hardware components for DC2

Hardware component id	Description	Input data assets (IDA)	Output data assets (ODA)
HW 1	AMI System –HEDNO	-	Metering data from smart meters and AMI of MV customers and large volume LV customers .csv
HW 2	SCADA System – HEDNO	-	SCADA/DMS events and SCADA measurements of P,Q,V, I for HV/MV substations – HEDNO .csv
HW 3	GIS System – HEDNO	-	MV/LV Network Topology and Equipment Status from GIS .json / .dwg
HW 4	SCADA System – IPTO	-	SCADA measurements of P, Q, V, I per substation .csv
HW 5	EMS System – IPTO	-	Energy measurements per substation .csv
HW 6	GIS System – IPTO	-	Spatial data regarding the location of transmission system components .png/.pdf/.jpeg
HW 7	Operations Database – EPA	-	Metering data of MV/LV customers .csv/.xlsx

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HW 8	Billing Database – EPA	-	Electricity prices and coefficients of regulated retail costs .xlsx
HW 9	CRM Database – EPA	-	Data regarding customer installations .xlsx

Workflow

The following sequential diagram and flow chart depict how the Demo Case will be implemented:

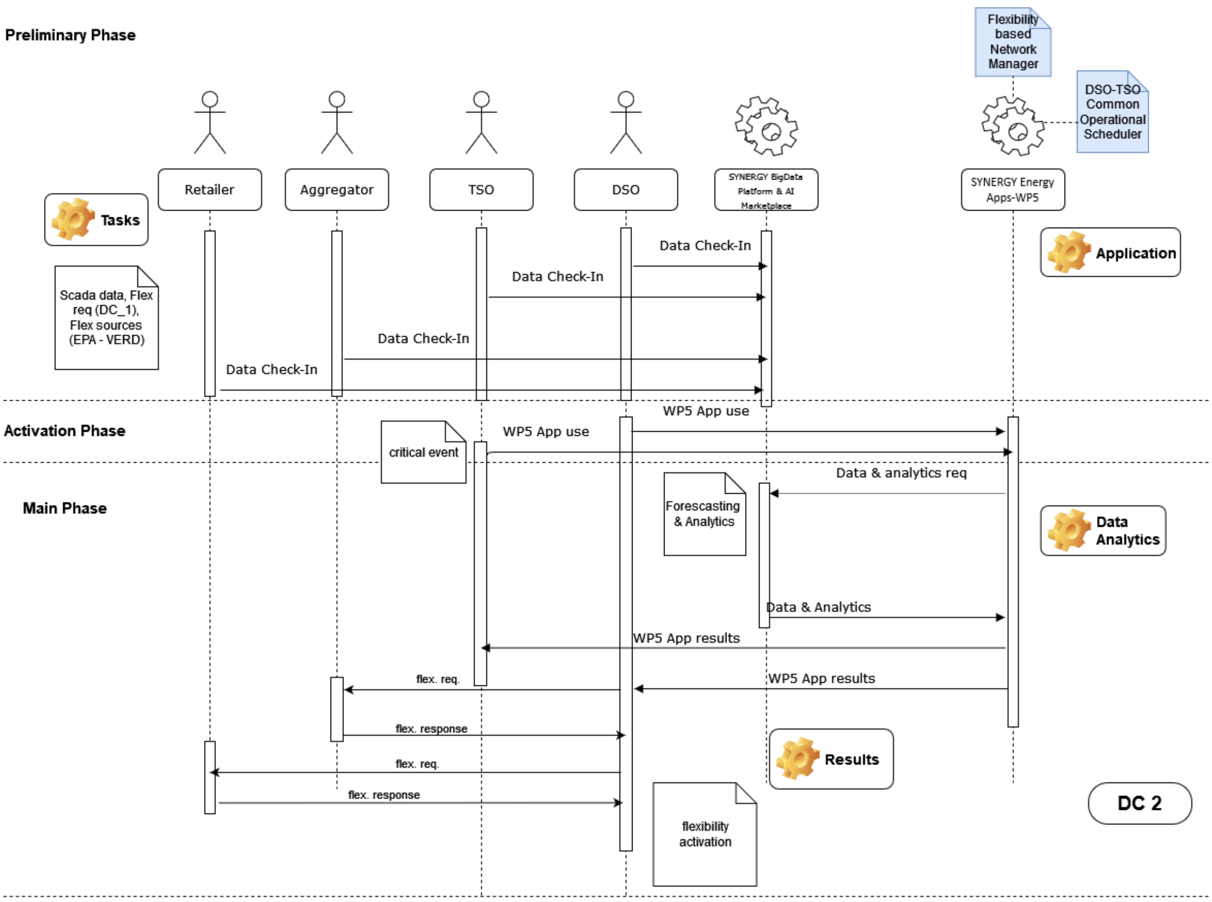

Figure 11: DC2 sequential diagram

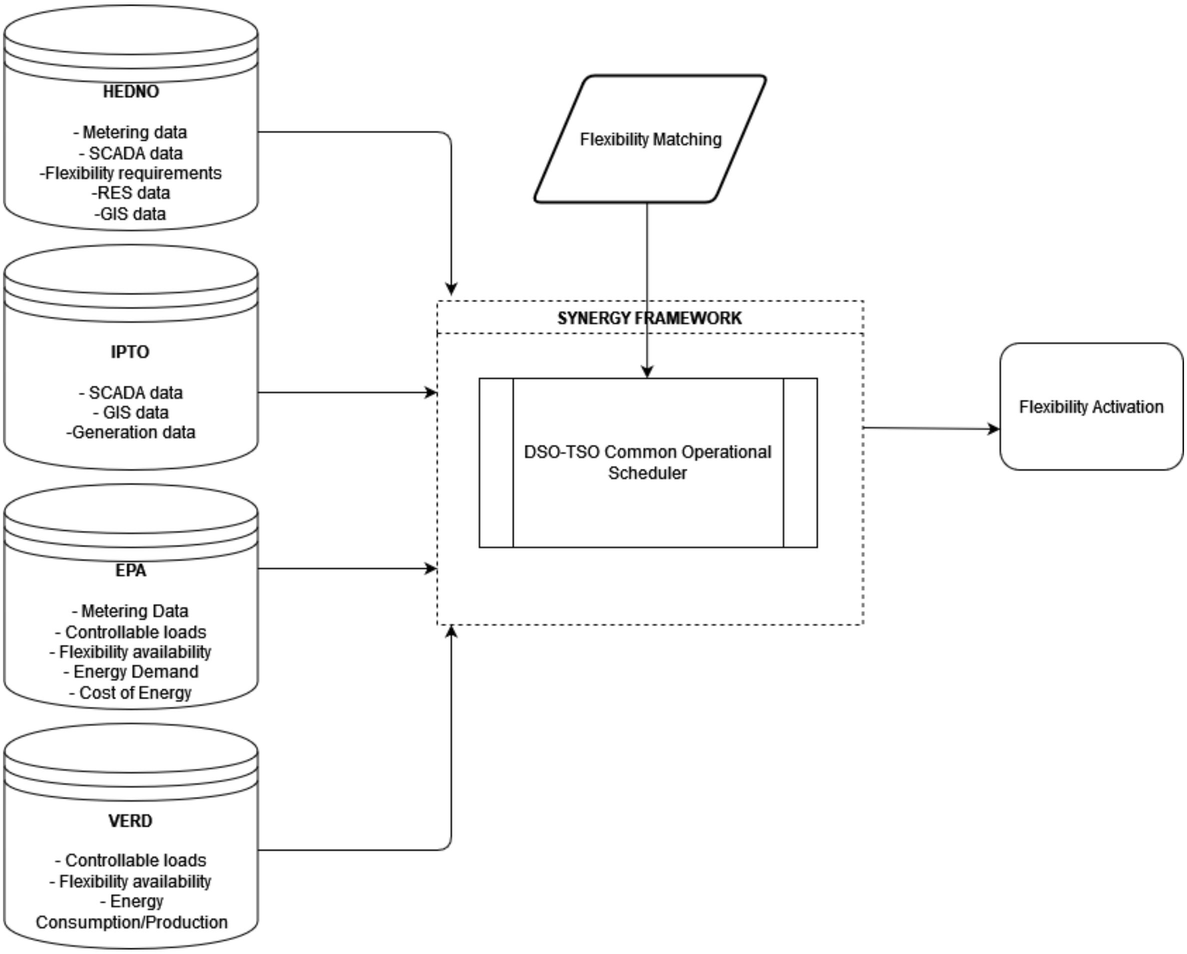

Figure 12: DC2 workflow flowchart

The Demo Case will be validated as follows, during both Demo runs:

<u>First Demo run:</u>

Validation Scenario 1: Data transmitted correctly to SYNERGY Platform

Preliminary phase: describe preparation processes

All data is pre-processed by the providing partner.

Activation phase: define the triggering event

Data is submitted to the SYNERGY platform.

Main phase: describe main processes of validation scenario

Data is successfully uploaded and accepted/processed by the Data Ingestion Services of the SYNERGY platform.

Data assets are checked to verify that they have been uploaded correctly.

Results: Uploaded data assets are processed and available in the SYNERGY platform.

Validation Scenario 2: Data received correctly from Flexibility Based Network Manager and DSO-TSO common operational Scheduling Application.

Preliminary phase: describe preparation processes

All data is processed and available in the platform.

Activation phase: define the triggering event

DSO-TSO Common Operational Scheduling Component of Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling application is invoked, through SYNERGY Platform.
Main phase: describe main processes of validation scenario
Check if DSO-TSO Common Operational Scheduling Component is able to find and load the correct data assets when they are invoked.
Results: DSO-TSO Common Operational Scheduling Component should contain the needed data to run.

First and Second Demo run:

Validation Scenario 3: Testing with multiple critical grid events requiring flexibility prioritization.
Preliminary phase: describe preparation processes
Different data sets are available on the SYNERGY platform that cover different possible critical grid events in order to test the tool.
Activation phase: define the triggering event
DSO-TSO Common Operational Scheduling Component is invoked, through SYNERGY Platform.
Main phase: describe main processes of validation scenario
Check DSO-TSO Common Operational Scheduling Component is able to process, identify and generate an outcome in different test scenarios.
Results: DSO-TSO Common Operational Scheduling Component should produce an outcome in all scenarios tested.

Validation Scenario 4: Operational schedule prioritizes flexibility needs of DSO and TSO.
Preliminary phase: describe preparation processes
A request is made by a DSO or TSO for available Flexibility due to flexibility needs.
Activation phase: define the triggering event
Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling application is invoked, through SYNERGY Platform.
Main phase: describe main processes of validation scenario
The DSO-TSO Common Operational Scheduling Component is able to process data and prioritizes the flexibility requirements of DSO and TSO, based on the results of Flexibility-Based Network Manager Component.
Results: A successful prioritization of flexibilities needs of DSO and TSO is produced.

Validation Scenario 5: Existing contracts/SLAs between network operators and flexibility providers cover the proposed scheduling.
Preliminary phase: describe preparation processes
A request is made by a DSO or TSO for available Flexibility due to flexibility needs.
Activation phase: define the triggering event
Flexibility-Based Network Manager and DSO-TSO Common Operational Scheduling application is invoked, through SYNERGY Platform.
Main phase: describe main processes of validation scenario
Each component is able to process data and try to match the requests with the available flexibility. Once that is done, the result is communicated back to DSO in order to proceed with activating the

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proposed schedule accordingly.
Results: The proposed schedule can be activated since existing contracts/SLAs between network operators and flexibility providers are already in place and cover the proposed scheduling.

5.1.2.2 Impact KPIs

The KPIs that will be assessed in this Demo Case are:

- Peak load demand reduction
- Size of congestions
- Frequency of congestions
- Congestion alleviation
- Active power deviation from flexible units
- Activated flexibility compared to available flexibility
- Flexibility Activation
- Flexibility Override
- Actual Flexibility on Contract
- Flexibility Request on Contract

5.1.2.3 Preliminary Evaluation Plan

The preliminary evaluation plan, during the first demo run, will consist mainly of making sure that all the applications and components developed, along with the corresponding analytics and algorithms, are working as intended and can provide reliable and feasible results. More specifically, the proposed flexibility schedule and its activation, should lead to a reduction in congestions and alleviation or avoidance of grid problems, which should be verified through the corresponding analytics/KPIs. Furthermore, the data needed and uploaded to the SYNERGY platform must be adequately provided and validated in order to ensure that the necessary requirements for the execution of the demo case are met.

After these pre-conditions are met, during the second demo run, the developed application will be evaluated by the increase in the amount of load capacity participating in flexibility schemes, by the overall activated flexibility compared to the available and by the revenues created from its utilization. These KPIs will be part of the evaluation during the second demo run, as such results can be calculated after the first demo run has produced its results, as described through the corresponding validation scenarios.

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5.1.3 Demo Case 3: Enhanced Network Asset Management and Planning

5.1.3.1 Validation Scenario

Description

The main aim of Demo Case 3 is to equip the Greek DSO, HEDNO and the Greek TSO, IPTO with a unique toolbox for Asset Management, towards increasing Network Availability and improving Network Resilience.

Smart metering data offered by HEDNO will be fused and analysed together with historical failures and interruptions data (residing in offline databases), visual and IR imagery coming from portable cameras employed for the network inspection, additional imagery data from cameras attached to drones (UAVs) providing supplementary information for network assets, geo-spatial data from GIS servers correlating assets and events with the geographical areas and SCADA information (from both HEDNO and IPTO), to provide better visibility into the network assets and proactively predict asset life or anticipated failures, optimize asset investments, prioritize reliability planning and point out common causes of asset failures, thus bringing asset management to an even more advanced level than current practices.

The following validation scenarios can be tested in order to make sure that the Demo Case performs as expected:

- Validation Scenario 1 – Data Ingestion
- Validation Scenario 2 – Heterogeneous Asset Data Ingestion
- Validation Scenario 3 - Health Index and Anticipated Failures Output
- Validation Scenario 4 – Data visualization
- Validation Scenario 5 – Predictive Maintenance Programs Output.

Objectives

Demo Case Objectives:

- Target 1: Increase the Network Availability
- Target 2: Improve the Network Resilience
- Target 3: Proactively predict asset life or anticipated failures

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- Target 4: Optimize asset investments
- Target 5: Right-size the assets
- Target 6: Reduce total cost of ownership
- Target 7: Evidence-based network planning and infrastructure sizing

Objectives/goals/targets of each validation scenario:

- Objective 1 - The SYNERGY Platform properly ingests the data submitted by the different users
- Objective 2 - The SYNERGY Platform is able to handle properly heterogeneous asset data
- Objective 3 - The SYNERGY platform scores a Health Index for all the input Assets and Anticipated Failures will be estimated.
- Objective 4 - All data, provided or derived, are correctly visualised
- Objective 5 – The SYNERGY Platform produces predictive maintenance programs.

Stakeholders

The involved stakeholders/partners of each validation scenario and their role in the VSs:

- IPTO – Data Owner, Data Provider, Data Consumer, Data Scientists
- HEDNO – Data Owner, Data Provider, Data Consumer, Data Scientists

Use cases

- Use case 5_7 – Enhanced monitoring of status and health (including VR navigation) of network components
- Use case 5_8 – Knowledge-based preventive maintenance scheduling for network assets

Available Data Assets

The following table contains the available data assets that are involved in Demo Case 3:

Table 20: Available Data Assets for DC3

Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform

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GR_IPTO_1	Measurements of HV substation	IPTO	Asset Management Optimization Application	Available in 1st Iteration
GR_IPTO_3	Spatial data regarding the location of transmission system components	IPTO	Asset Management Optimization Application	Available in 1st Iteration
GR_HEDNO_1	"Metering data from smart meters and AMI of MV customers (1 year worth of historical data of LV customers)"	HEDNO	Asset Management Optimization Application	Available in 1st Iteration
GR_HEDNO_2	Metering data from normal meters of LV customers	HEDNO	Asset Management Optimization Application	Available in 1st Iteration
GR_HEDNO_3	SCADA/DMS events and SCADA measurements of P,Q,V, I for HV/MV substations	HEDNO	Asset Management Optimization Application	Available in 1st Iteration
GR_HEDNO_5	RES production measurements for	HEDNO	Asset Management	Available in 1st Iteration

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	connections in Distribution Network		Optimization Application	
GR_HEDNO_6	MV/LV Network Topology and Equipment Status from GIS	HEDNO	Asset Management Optimization Application	Available in 1st Iteration
GR_HEDNO_7	Failures and Outage Management Information	HEDNO	Asset Management Optimization Application	Available in 1st Iteration
GR_HEDNO_8	Visual and IR images of transformers	HEDNO	Asset Management Optimization Application	Available in 1st Iteration

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Energy applications

The following table contains the energy applications that play a role in Demo Case 3:

Table 21: Energy Applications to be tested for DC3

Energy app name	Components	Input data assets (IDA)	Output data assets (ODA)
Asset Management Optimization Application	The Asset Management Optimization Application supplies the DSOs' and TSOs' maintenance operators with a variety of components that facilitate maintenance management. Maintenance operators will be equipped with a number of analytics and forecasts that integrate the available data and provide new perspectives about the asset management. For example, this application includes components that model the overall health score of each asset instance under maintenance component and provide forecasted scenarios about failures of assets. ETRA	IDA 1 - IPTO (GR_IPTO_1,3) IDA 2 – HEDNO (GR_HEDNO_1,2,3,5,6,7,8)	ODA 1 – IPTO (Historical data, Real-time data, Picture-based indicators, Asset health indicators, Failure probability per asset (short-term), Failure probability per asset (medium-term), Failure probability per asset (long-term), Early alerts) ODA 2 – HEDNO (Historical data, Real-time data, Picture-based indicators, Asset health indicators, Failure probability per asset (short-term), Failure probability per asset (medium-term), Failure probability per asset (long-term), Early alerts)

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Data analytics

The analytics that are expected to be used in DC3 are introduced in Table 22. Data analytics are executed in the SYNERGY Platform, with the exception of simulation algorithms that involve power flow calculations and are executed offline. Those cases are mentioned below in the description as 'executed offline'.

Table 22: Data analytics used in DC3

Data Analytics name	Description	Input data assets (IDA)	Output data assets (ODA)
Asset health score calculation	Based on the latest available measurements, the asset will be classified under a certain health score/level (ETRA)	Dataset including measurements of similar assets and resulting health score assessment (for model preparation) Fresh measurements for asset under maintenance (HEDNO, IPTO)	Current State of Health of asset under maintenance (HEDNO, IPTO)
Picture analysis	Extract relevant metrics from picture sources. (ETRA)	Infrared pictures Drone pictures (HEDNO, IPTO)	Temperature Presence Smoke (HEDNO, IPTO)
Failure probability per asset (short-term)	Determine the probability of failure (per asset and addressed issue) in the next 30 days. (ETRA)	Run-to-failure datasets covering addressed asset type, issue type and time range (HEDNO, IPTO)	Failure prediction model (short-term) (HEDNO, IPTO)
Failure probability per asset (medium-term)	Determine the probability of failure (per asset and addressed issue) in the next 6 months. (ETRA)	Run-to-failure datasets covering addressed asset type, issue type and time range (HEDNO, IPTO)	Failure prediction model (medium-term) (HEDNO, IPTO)

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Failure probability per asset (long-term)	Determine the probability of failure (per asset and addressed issue) in the next 5 years. (ETRA)	Run-to-failure datasets covering addressed asset type, issue type and time range (HEDNO, IPTO)	Failure prediction model (long-term) (HEDNO, IPTO)
Event correlations	Upon occurrence of a particular sequence of events/alerts, provide early alerts on probable occurrence of future events/alerts The analytic will be based on sequence prediction algorithms trained with the historical alerts recorded by the grid operator. (ETRA)	Power grid event/alert log (HEDNO, IPTO)	Event correlation model (HEDNO, IPTO)

<u>Hardware Components</u>

The following table contains hardware components that are involved in Demo Case 3:

Table 23: Hardware components used in DC3

Hardware component id	Description	Input data assets (IDA)	Output data assets (ODA)
HW 1	SCADA System –HEDNO	-	SCADA/DMS events and SCADA measurements of P, Q, V, I for HV/MV substations .csv
HW 2	GIS System – HEDNO	-	MV/LV Network Topology and Equipment Status from GIS .json / .dwg

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HW 3	SCADA System – IPTO	-	SCADA measurements of P, Q, V, I from HV substations .csv
HW 4	EMS System – IPTO	-	Energy Measurements per substation .csv
HW 5	GIS System – IPTO	-	Spatial data regarding the location of transmission system components .png/.pdf/.jpeg

<u>Workflow</u>

The following sequential diagram and flow chart depict how the Demo Case will be implemented:

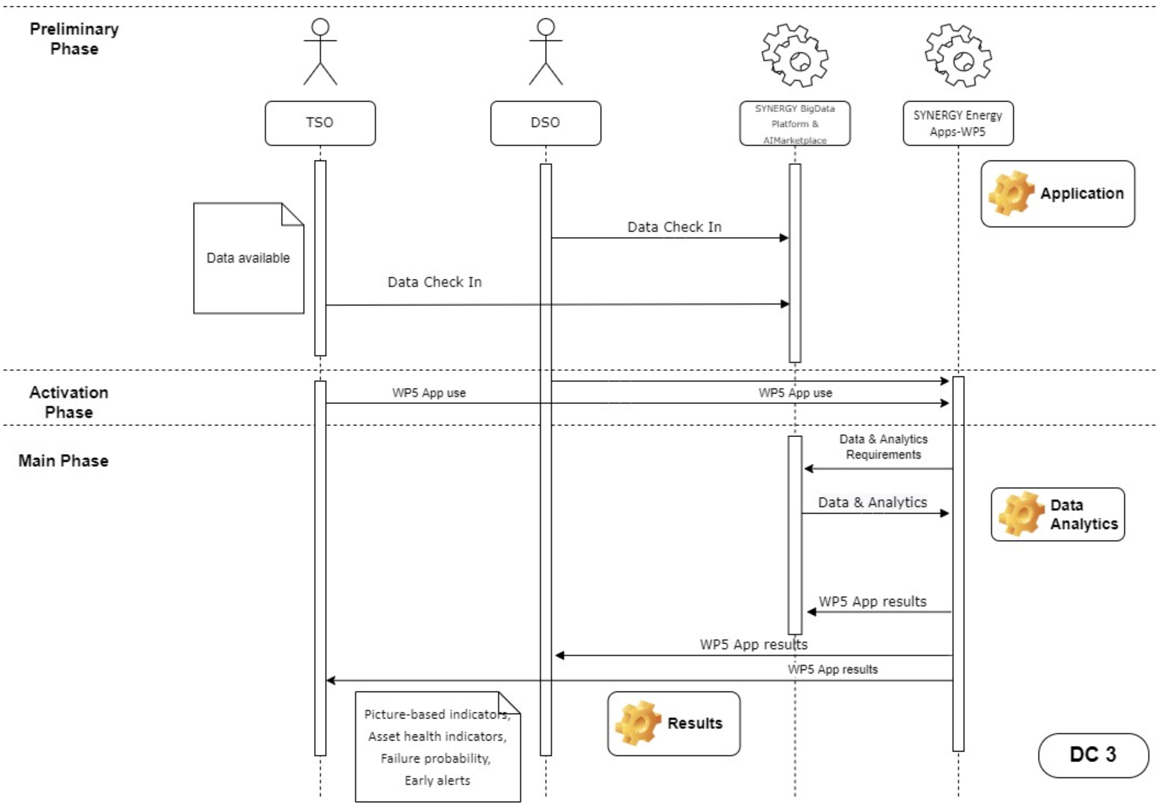

Figure 13: DC3 sequential diagram

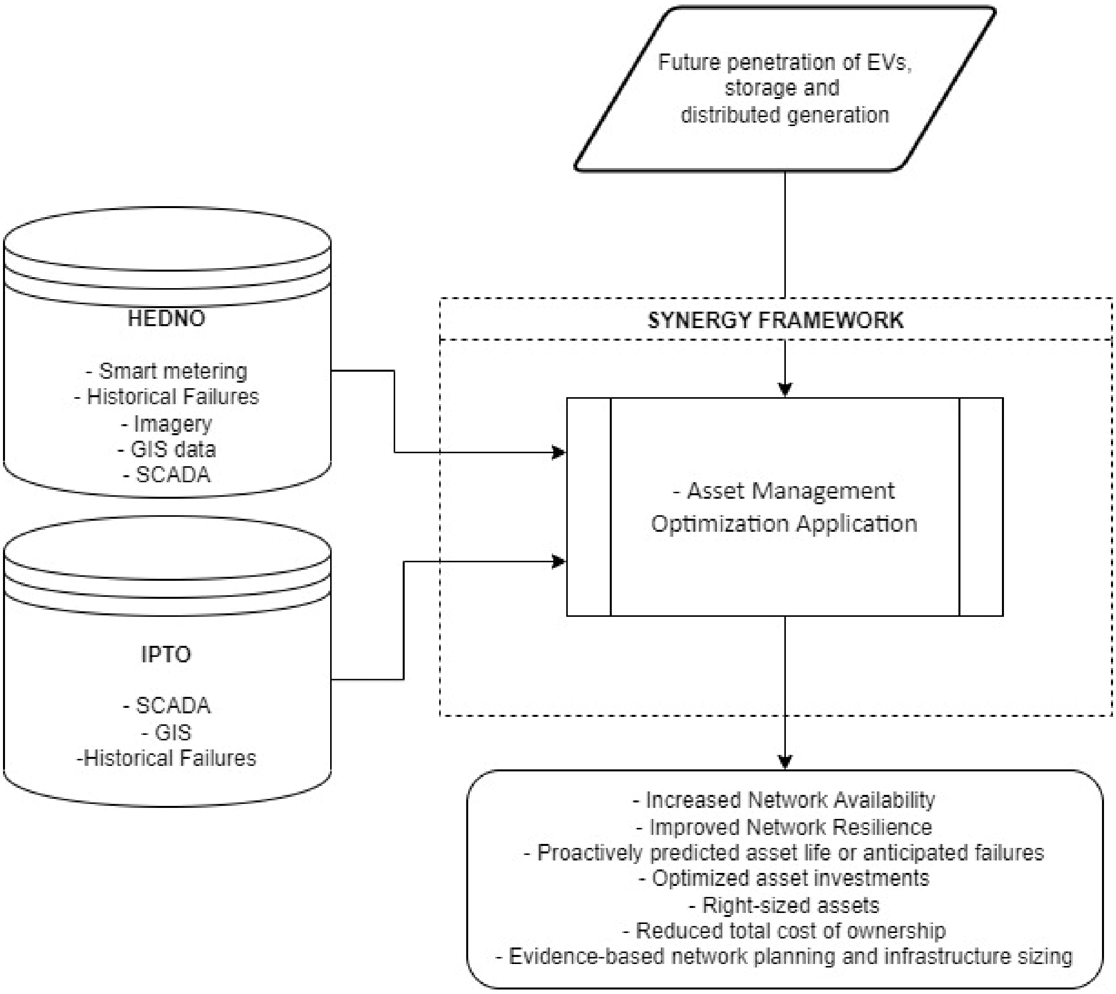

Figure 14: DC3 workflow flowchart

First Demo run:

Validation Scenario 1 – Data Ingestion

Preliminary phase:

All data is pre-processed by the providing partner and submitted to the platform. All data is pre-processed by the Data Ingestion Services of the platform.

Activation phase:

The Asset Management Optimization Application is invoked.

Main phase:

The Asset Management Optimization Application should invoke the SYNERGY Platforms APIS and obtain all the necessary data.

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Results:

The Asset Management Optimization Application should contain the data for all the submitted assets.

Validation Scenario 2 - Heterogeneous Asset Data Ingestion

Preliminary phase:

All data is pre-processed by the providing partner and submitted to the platform.

All data is pre-processed by the Data Ingestion Services of the platform.

Activation phase:

The Asset Management Optimization Application is invoked.

Main phase:

The Asset Management Optimization Application should invoke the SYNERGY Platforms APIs , obtain all the necessary data.

Results:

The Asset Management Optimization Application should contain the data for all the submitted assets and discern them no matter their heterogeneous nature.

First and Second Demo run:

Validation Scenario 3 - Health Index and Anticipated Failures Output

Preliminary phase:

All data is pre-processed by the providing partner and submitted to the platform.

All data is pre-processed by the Data Ingestion Services of the platform.

Activation phase:

The Asset Management Optimization Application is invoked.

Main phase:

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The Asset Management Optimization Application should invoke the SYNERGY Platforms APIs, obtain all the necessary data.
The Asset Management Optimization should deploy the appropriate modules.

Results:

The Asset Management Optimization Application should output a Heal Index Scoring and Anticipated Failures for all the requested Assets.

Validation Scenario 4 - Data visualization

Preliminary phase:

All data is pre-processed by the providing partner and submitted to the platform.

All data is pre-processed by the Data Ingestion Services of the platform.

Activation phase:

The Asset Management Optimization Application is invoked.

Main phase:

The Asset Management Optimization Application should invoke the SYNERGY Platforms APIs, obtain all the necessary data.

The Asset Management Optimization should deploy the appropriate modules.

Results:

The Asset Management Optimization Application should correctly display in a GUI all the data, either provided or derived.

Validation Scenario 5 - Predictive Maintenance Programs Output

Preliminary phase:

All data is pre-processed by the providing partner and submitted to the platform.

All data is pre-processed by the Data Ingestion Services of the platform.

Activation phase:

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The Asset Management Optimization Application is invoked.

Main phase:

The Asset Management Optimization Application should invoke the SYNERGY Platforms APIs, obtain all the necessary data.

The Asset Management Optimization should deploy the appropriate modules.

Results:

The Asset Management Optimization Application should produce predictive maintenance programs for all the requested Assets.

5.1.3.2 Impact KPIs

The KPIs that will be assessed in this demo case are:

- Distribution Equipment Maintenance Cost
- Transmission Equipment Maintenance Cost
- Fraction or percentage of the customers experiencing more than N interruptions
- Effectiveness of the Asset Health Estimation

5.1.3.3 Preliminary Evaluation Plan

The preliminary evaluation plan, during the first demo run, will consist mainly of making sure that all the applications and components developed, along with the corresponding analytics and algorithms, are working as intended and can ingest all the provided data correctly, handle heterogeneous data and have reasonable outputs according to the application's description and requirements. During the second demo run, the developed applications will be evaluated as a whole and the relevant KPIs, as described above, will be taken into consideration, in order to validate the application and ensure that SYNERGY's goals are met.

5.1.4 Demo Case 4: Retailer portfolio analytics and elasticity (price-based flexibility) estimation for the provision of services to network operators

5.1.4.1 Validation Scenario

Description

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Demo Case 4, Retailer portfolio analytics and elasticity (price-based flexibility) estimation for the provision of services to network operators, will be based on a complete toolbox for energy retailers enabling comprehensive portfolio analysis, towards optimizing a series of business objectives. In more detail, the toolbox will utilize smart meter and consumption data provided from HEDNO (DSO), together with weather data, energy market/price data from IPTO (TSO) and energy exchange as well as customer and building data from EPA (Retailer) to offer a holistic view and respective insights over the customer portfolio of electricity retailers. The tools will include pre-trained predictive models that lead to improved business performance and will reduce operation expenses from daily operations through better forecasting. Moreover, customer data and segmentation will enable in-depth study aiming at the development of targeted innovative products and services for each cluster.

In order to achieve this demo case, all the relevant data need to be available, through the SYNERGY platform, to the Portfolio Analytics and Management Application and the Personalized Energy Analytics Application in order to analyse them and provide the expected forecasts and clustering.

The following validation scenarios can be tested to make sure that the outcome is as expected:

- Validation Scenario 1: Data uploaded correctly to the SYNERGY Platform
- Validation Scenario 2: Data received correctly from the SYNERGY Applications
- Validation Scenario 3: Retrieve and evaluate short-term and long-term forecasts
- Validation Scenario 4: Retrieve and compare customer clusters
- Validation Scenario 5: Data are displayed correctly on the GUI

Objectives

Demo case Objectives:

Objective 1: Improvement in accuracy of demand forecasts (in the short- and mid-term) for the retailer in order to improve operations and reduce balancing costs

Objective 2: Study portfolio clusters to develop customized and targeted products and services for specific segments in order to increase customer loyalty

Objectives of the validation scenarios:

- Objective for VS 1: Data is successfully and accurately uploaded from all demo partners to the SYNERGY platform

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- Objective for VS 2: Data available on the platform is successfully and accurately transmitted to developed SYNERGY Applications
- Objective for VS 3: Forecasts for various time horizons are obtained using available pre-trained analytics along with their Mean Absolute Percentage Error (MAPE) metrics.
- Objective for VS 4: Customer clusters are successfully obtained based on temporal, spatial, socioeconomic and consumption data available to the respective application

Stakeholders

Clarify the involved stakeholders/partners of each validation scenario and what is their role in it.

- EPA: both a Data Owner and Data Provider as far as their customer data are concerned and especially commercial and socio-economic data, but also data consumer of extra data, such as measurements and market prices that enable further segmentation of their portfolio and better forecasting. To perform the needed analytics, EPA will also get the role of Data Scientist.
- HEDNO: as they are the Greek Distribution System Operator, they are Data Owner and Data Provider of many data regarding electricity consumers and especially measurements
- IPTO: as they are the Greek Transmission System Operator, they are Data Owner and Data Provider of many data regarding electricity network that are needed for load forecasting

Use cases

Specify which UCs are involved in each validation scenario.

- UC_6_1: Optimized energy transactions (retailers) based on accurate demand forecasting
- UC_6_2: Imbalance risk reduction through implicit demand side management strategies (elasticity-based)
- UC_6_3: Retailer portfolio analytics towards the extraction of useful insights
- UC_6_7: Personalized energy analytics, performance monitoring and energy efficiency guidance for consumers

Available Data Assets

The following table contains the available data assets that are involved in Demo Case 4:

Table 24: Available data assets used in DC4

Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform
GR_HEDNO_1	Metering data from smart meters and AMI of MV and LV customers	HEDNO	Portfolio Analytics and Management Application, Personalized Energy Analytics Application	Available in 1st Iteration
GR_HEDNO_2	Metering data from normal meters of LV customers	HEDNO	Portfolio Analytics and Management Application, Personalized Energy Analytics Application	Available in 1st Iteration
GR_HEDNO_3	SCADA/DMS events and SCADA measurements of P, Q, V, I for HV/MV substations	HEDNO	Portfolio Analytics and Management Application	Available in 1st Iteration
GR_HEDNO_4	Flexibility requirements at DSO level	HEDNO	Portfolio Analytics and Management Application	Available in 1st Iteration
GR_HEDNO_5	RES production measurements for connections in Distribution Network	HEDNO	Portfolio Analytics and Management Application	Available in 1st Iteration
GR_IPTO_1	Measurements of HV substation	IPTO	Portfolio Analytics and Management Application	Available in 1st Iteration
GR_IPTO_2	Data about short- and mid-term flexibility requirements based on the needs of the transmission system operator	IPTO	Portfolio Analytics and Management Application	Available in 1st Iteration
GR_IPTO_4	Aggregated generation forecast	IPTO	Portfolio Analytics and Management Application	Available in 1st Iteration

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Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform
	for the Greek transmission system			
GR_EPA_1	Electricity consumption of EPA's customer portfolio	EPA	Portfolio Analytics and Management Application	Available in 1st Iteration
GR_EPA_2	SMP and ex-post SMP values	EPA	Portfolio Analytics and Management Application	Available in 1st Iteration
GR_EPA_3	Electricity prices and coefficients of regulated retail costs	EPA	Personalized Energy Analytics Application	Available in 1st Iteration
GR_EPA_4	Data regarding each customer installation, e.g. location, usage type, business category etc	EPA	Portfolio Analytics and Management Application, Personalized Energy Analytics Application	Available in 1st Iteration
GR_EPA_5	Consumption of EPA's MV customers	EPA	Portfolio Analytics and Management Application, Personalized Energy Analytics Application	Available in 1st Iteration
GR_EPA_6	Consumption of EPA's LV customers	EPA	Portfolio Analytics and Management Application, Personalized Energy Analytics Application	Available in 1st Iteration
GR_HEDNO_DN_3	Controllable loads on customer premises	EPA	Portfolio Analytics and Management Application	
GR_HEDNO_DN_6	Energy Demand and Production Forecasts	IPTO	Portfolio Analytics and Management Application	Available in 1st Iteration

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Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform
GR_HEDNO_DN_7	RES Production at HV	IPTO	Portfolio Analytics and Management Application	Available in 1st Iteration
GR_VERD_DN_2	Temperature data (short-mid-long-term forecasting) to facilitate forecasting of demand in different time horizons	?	Portfolio Analytics and Management Application	
GR_EPA_DN_1	Data related to the installations of all MV, LV Greek customers, e.g. zip code, usage type, billing category, building data	HEDNO	Portfolio Analytics and Management Application, Personalized Energy Analytics Application	

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Energy applications

The following table contains the energy applications that are involved in Demo Case 4:

Table 25: Energy applications tested within DC4

Energy app name	Components	Input data assets (IDA)	Output data assets (ODA)
Portfolio Analytics and Management Application	Portfolio Pattern Forecasting Engine will be used to obtain accurate demand forecasts based on consumption patterns Customer Segmentation Engine will be used to obtain customer segments based on various criteria Wholesale Market Participation Decision Support System will use information provided by the other components to define optimal retailer operations based on DSM strategies that minimize balancing costs - ETRA	IDA 1 – EPA (GR_EPA_1, GR_EPA_2, GR_EPA_3, GR_EPA_4, GR_EPA_5, GR_EPA_6)	ODA 1 - Historical data per customer ODA 2 - Historical data at portfolio-level ODA 3 - Short-term imported/exported energy forecast ODA 4 - Long-term imported/exported energy forecast ODA 5 - Temporal Energy Usage clusters ODA 8 - Elasticity profiles per customer ODA 9 - Elasticity profiles clusters ODA 10 - Socioeconomic clusters ODA 11 - Optimal dynamic tariff prices ODA 12 - Day-ahead price forecast ODA 13 - Intra-day price forecast
Personalized Energy Analytics Application	Personalized Energy Analytics Engine component will be used to study consumption patterns and obtain targeted suggestions for improving energy performance	IDA 1 – EPA (GR_EPA_1, GR_EPA_2, GR_EPA_3, GR_EPA_4, GR_EPA_5, GR_EPA_6)	ODA 1 - Historical data per customer ODA 2 - Temporal energy usage clusters ODA 3 - Socioeconomic clusters

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	- ETRA		

Data analytics

The following table contains the data analytics that are involved in Demo Case 4 and are executed in the SYNERGY Platform:

Table 26: Data analytics tested within DC4

Data Analytics name	Description	Input data assets (IDA)	Output data assets (ODA)
Aggregate Portfolio Imported Energy	Provide portfolio-level aggregated metrics for further analytics	Customer imported energy	Portfolio imported energy
Build short-term Portfolio-level Imported Energy forecast model	Train a specific model to forecast next 6 hours of overall portfolio imported energy metric	Portfolio imported energy Weather data Historical TSO area demand	Imported Energy Forecast model (short-term)
Build long-term Portfolio-level Imported Energy forecast model	Train a specific model to forecast next 5 years of overall portfolio imported energy metric	Portfolio imported energy Weather data Historical TSO area demand	Imported Energy Forecast model (long-term)
Short-term Imported Energy forecasts	Executes Imported Energy Forecast model to get next 24 hours forecast	Weather forecasts TSO area demand prevision	Grid Imported energy forecast
Short-term Exported Energy forecasts	Executes Exported Energy Forecast model to get next 24 hours forecast	Weather forecasts TSO area generation prevision	Grid exported energy forecast

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Long-term Imported Energy forecasts	Executes Long-term Imported Energy Forecast model to get next 5 years forecast	Weather projections Portfolio composition projection DER share projection Historical power demand	Grid imported energy forecast
Long-term Exported Energy forecasts	Executes Long-term Exported Energy Forecast model to get next 5 years forecast	Weather projections DER share projection Historical power supply	Grid exported energy forecast
Temporal Energy Usage profiling	Gain further understanding on the composition of the customer portfolio by analysing and identifying common patterns on the amount and temporal use of the energy, which can be used to identify similar peers	Customer imported energy	Clusters of customers Clusters characterization Average characteristics of clusters (centroids)
Socioeconomic profiling	Gain further understanding on the composition of the customer portfolio by building groups of customers with similar socioeconomic characteristics, which will be relevant for customer peer comparison	Customer Socioeconomic data Customer contractual data	Clusters of customers Clusters characterization Average characteristics of clusters (centroids)
Elasticity profiling	Model how each one of the customers in the portfolio reacts to price-based signals (dynamic tariff schemes), on different contextual frames (dependent on time period, day of the week and other parameters)	Customer imported energy Customer contractual data Dynamic tariff price series	Customer elasticity profiles
Elasticity clustering	Based on the results of the individual elasticity profiles, those will be used to group customers	Customers elasticity profiles	Clusters of customers Clusters characterization

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	presenting similar behaviours in order to facilitate the management of elasticity to the retailer		
Short-term imported energy forecast	Periodically updates the short-term forecast (next 6 hours) of the demand of the portfolio. Due to the potential unavailability of portfolio data in a near real-time basis, this forecast will depend mostly on related exogenous parameters (weather and TSO area forecasts)	Historical portfolio imported energy Historical weather data Historical TSO area demand data	Portfolio imported energy
Optimal dynamic tariff calculation	Based on deviations from day-ahead and intra-day portfolio demand forecasts, and by utilising the information extracted by the portfolio elasticity profiling and clustering, the optimum set of price-signals (prices to be applied to the dynamic tariff) expected to correct the deviations during the following short-term (6 hours) is provided	Day-ahead portfolio demand forecasts Short-term portfolio demand forecasts Portfolio elasticity clusters	Dynamic tariff prices
Day-ahead price forecast	Time series prediction of the hourly prices of the day-ahead market based on regression methods displayed prior to the publication of results on D-1	Historical day-ahead prices Historical power demand Historical power supply Historical weather data Historical commodities price	Day-ahead price forecast model
Intra-day price forecast	Time series prediction of the hourly prices of the multiple sessions of intra-day market based on regression or classification methods displayed prior to the publication of results on D-1 and before contract session close	Historical intra-day prices Historical power demand Historical power supply Historical weather data Historical commodities price	Intra-day price forecast model

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Yearly demand peaks	Predictions which hours in the day we expect peak demand at grid level (over a year)	Historical power demand Historical weather data Historical commodities price	Peak hours
Outlier detection	Anomaly/outlier detection in energy demand	Historical power demand Historical weather data Historical commodities price	Not expected demand/Outliers

<u>Hardware Components</u>

The following table contains the hardware components that are involved in Demo Case 4

Table 27: Hardware components of DC4

Hardware component id	Description	Input data assets (IDA)	Output data assets (ODA)
HW 1	AMI System – HEDNO		Metering data from smart meters and AMI of MV customers and large volume LV customers .csv
HW 2	SCADA System – HEDNO		SCADA/DMS events and SCADA measurements of P,Q,V, I for HV/MV substations .csv
HW 3	SCADA System – IPTO		SCADA measurements of P, Q, V, I per substation .csv
HW 4	EMS System (including MMS and MSS) – IPTO		Energy measurements per substation .csv
HW 5	Operations Database– EPA		Aggregated demand of MV/LV customers .csv

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HW 6	Billing Database– EPA		Electricity prices and coefficients of regulated retail costs and metering data .csv
HW 7	CRM Database– EPA		Data regarding customer installations .csv

<u>Workflow</u>

The following sequential diagram and flow chart depict how the Demo Case will be implemented:

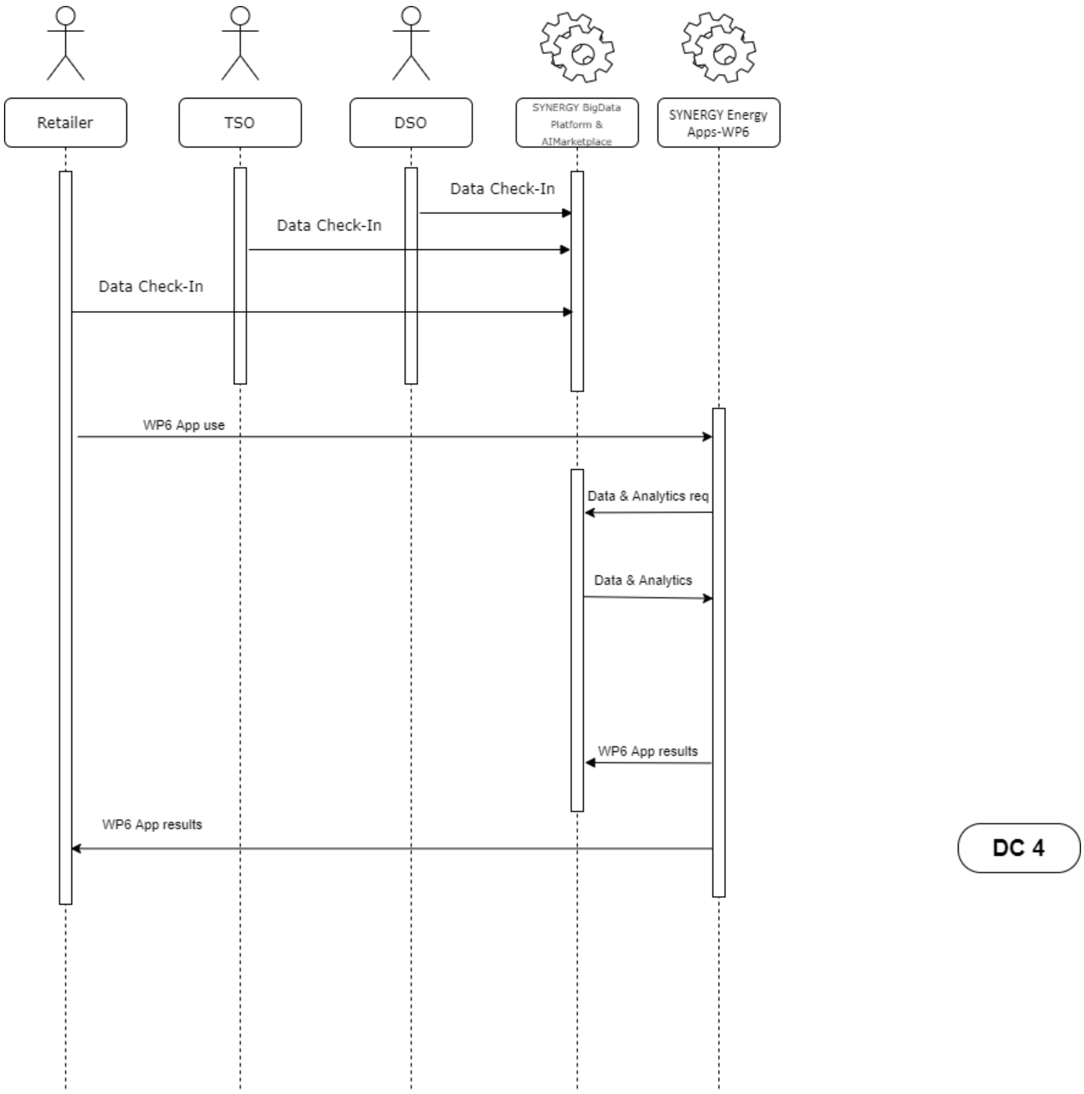

Figure 15: DC4 Sequential diagram

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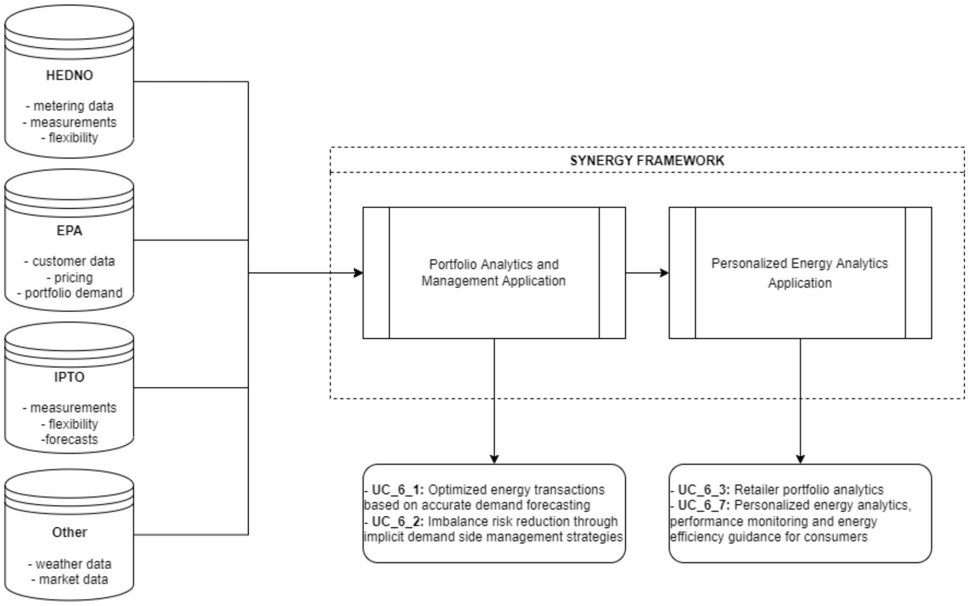

Figure 16: DC4 workflow flowchart

The Demo Case will be validated as follows, during both Demo runs:

First Demo run:

Validation Scenario 1: Data uploaded correctly to SYNERGY Platform
Preliminary phase: describe preparation processes
All data is pre-processed by the providing partners and uploaded to the platform.
All data is processed by the Data Ingestion Services of the platform.
Activation phase: define the triggering event
User searches the data assets that are available in the platform.
Main phase: describe main processes of validation scenario
Data assets are checked to verify that they have been uploaded correctly
Results:
Uploaded data assets are processed and available in the platform

Validation Scenario 2: Data received correctly from SYNERGY Applications
Preliminary phase: describe preparation processes
All data is processed and available in the platform.
Activation phase: define the triggering event
Relevant Synergy Applications (Portfolio Analytics and Management Application, Personalized Energy Analytics Application) are invoked
Main phase: describe main processes of validation scenario
Check if relevant Synergy Applications find and load the correct data assets when they are invoked
Results:
Relevant Synergy Applications should contain the needed data to run

First and Second Demo run:

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Validation Scenario 3: Retrieve short-term and long-term forecasts
Preliminary phase: describe preparation processes
Portfolio Analytics and Management Application contains the needed data to run
Activation phase: define the triggering event
This Application's analytics regarding forecasts are requested by the user
Main phase: describe main processes of validation scenario
Check if the Application returns the requested forecast and its MAPE metrics
Results:
Portfolio Analytics and Management Application returns a forecast to the user

Validation Scenario 4: Retrieve customer clusters
Preliminary phase: describe preparation processes
Relevant Synergy Applications (Portfolio Analytics and Management Application, Personalized Energy Analytics Application) contain the needed data to run
Activation phase: define the triggering event
These Applications' analytics and functionalities regarding customer segmentation are requested by the user
Main phase: describe main processes of validation scenario
Check if the Applications return the requested clusters and if the results make sense
Results:
Relevant Synergy Applications return information regarding customer clusters to the user

Validation Scenario 5: Data are displayed correctly on the GUI
Preliminary phase: describe preparation processes
Relevant Synergy Applications (Portfolio Analytics and Management Application, Personalized Energy Analytics Application) contain the needed data to run
Activation phase: define the triggering event
These Applications are invoked or user uses their functionalities.
Main phase: describe main processes of validation scenario
Check if available input and output data assets are displayed correctly on the GUI
Results:
Relevant Synergy Applications have charts, diagrams and tables to display relevant data

5.1.4.2 Impact KPIs

The impact KPIs that will be used in this DC are the ones presented in the table below

KPI ID	KPI name	KPI impact category	KPI aspect
17	Percentage change of energy consumption for the consumer(a) and the portfolio (b)	Energy	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency

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KPI ID	KPI name	KPI impact category	KPI aspect
20	Demand forecasting accuracy	Energy	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency, Generation/Demand forecasting
22	GHG Emissions reduction	Environmental	Emissions

More specifically, Portfolio Analytics and Management Application will use data provided by network operators and EPA to provide forecasts for energy market prices, total demand and EPA's portfolio demand that will improve EPA's daily operations as a retailer. These forecasts will be compared to actual data in order to calculate accuracy, deviations and resulting charges and financial benefit.

Customer segmentation that will result from this application and will also be used in Personalized Energy Analytics Application will provide clusters on which new targeted products and services can be developed by a retailer. EPA's portfolio data along with measurement data will be used for this segmentation but there is not a specific threshold for clustering results since they cannot be directly quantified.

5.1.4.3 Preliminary Evaluation Plan

The preliminary evaluation plan, during the first demo run, will consist mainly of making sure that all the applications and components developed, along with the corresponding analytics and algorithms, are working as intended and can provide reliable and feasible results. More specifically, KPIs related to forecasting accuracy and resulting charges and savings will be evaluated during the 1st round since all relevant data will be available when the respective apps are delivered. The data needed and uploaded to the SYNERGY platform must be adequately provided and validated in order to ensure that the necessary requirements for the execution of the demo case are met.

After these pre-conditions are met, during the second demo run, the developed applications will be evaluated as a whole, in order to ensure that all of SYNERGY's goals are met successfully. Based on the evaluation, need for modifications may occur so updated apps will be tested as part of the 2nd round of evaluation.

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5.1.5 Demo Case 5: Flexibility segmentation, classification and clustering towards VPP configuration for demand response

5.1.5.1 Validation Scenario

Description

Demo case 5, "Flexibility segmentation, classification and clustering towards VPP configuration for demand response", aims at facilitating the management of demand and flexibility profiles in order to forecast and decide upon the optimal management of flexibility resources (demand, generation and storage).

The realisation of the demo case is based on the validation of the Flexibility Analytics and Consumer-Centric DR Optimization Application created within SYNERGY and aiming at facilitating the management of demand and flexibility profiles in order to forecast and decide upon the optimal management of flexibility resources (demand, generation and storage).

The main inputs for the AI analytics that will be performed within the tool will be smart metering data, sub-metering data from one local prosumer and one commercial customer (VERD's clients), along with, IoT from prosumer premises, local generation data, local energy storage data and weather data. HEDNO and IPTO will also provide flexibility requirements which, along with the aforementioned input data, will allow for the segmenting and classification of flexibility profiles at different spatio-temporal granularity in order to establish optimal VPP composition for the delivery of grid services to HEDNO and IPTO.

The following validation scenarios can be tested in order to make sure that the outcome is as expected:

- Validation Scenario 1: Data transmitted correctly to the SYNERGY Platform
- Validation Scenario 2: Data received correctly from the Flexibility Analytics and Consumer-Centric DR Optimization Application through the SYNERGY Platform.
- Validation Scenario 3: The Flexibility Analytics and Consumer-Centric DR Optimization Application produces flexibility profiles at different spatio-temporal granularity
- Validation Scenario 4: The VPP configuration engine produces VPP composition that matches the local DSO's and TSO's flexibility requirements.

Objectives

Demo case objectives

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

- Target 1: Perform and benefit from flexibility analytics: Optimisation of energy profiles towards flexibility provision
- Target 2: Enable optimized, non-intrusive flexibility activation and definition of Demand Response strategies
- Target 3: Meet flexibility requirements from HEDNO and IPTO and enable the provision of relevant services to the Network Operators
- Target 4: VPP configuration for services provision

Objectives of the validation scenarios:

- Objective 1: Data is successfully and accurately uploaded from all demo partners to the SYNERGY platform.
- Objective 2: Data is successfully and accurately transmitted to Flexibility Analytics and Consumer-Centric DR Optimization Application through the SYNERGY Platform.
- Objective 3: Energy profiles are optimised towards flexibility provision.
- Objective 4: Optimized, non-intrusive flexibility activation and definition of Demand Response strategies are enabled.
- Objective 5: Flexibility requirements from HEDNO and IPTO are met and the provision of the relevant services to the Network Operators is enabled.

<u>Stakeholders</u>

Stakeholders involved are:

- HEDNO: DSO, Data Owner and Data Provider and Data Broker of data regarding electricity consumers and especially measurements
- IPTO: TSO, Data Owner and Data Provider and Data Broker of data regarding electricity consumers and especially measurements
- VERD: Aggregator/ESCO, Data Owner, Provider, Broker and Consumer as well as Data Management and Services provider.

<u>Use cases</u>

- UC_6_4: Flexibility segmentation, classification and clustering
- UC_6_5: VPP configuration for the provision of ancillary services to the grid

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- UC_6_9: Establishment of bilateral flexibility contracts between aggregators and flexibility providers

Available Data Assets

The data assets that will be used to develop DC 5 are introduced in Table 28.

Table 28: Available data assets for DC5

Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform
GR_VERD_1	Energy imported from the Grid (kWh) for residential and commercial customer	VERD	Flexibility Analytics and Consumer-Centric DR Optimization	Available in 1st Iteration
GR_VERD_2	Energy exported to the Grid (kWh) for residential and commercial customer	VERD	Flexibility Analytics and Consumer-Centric DR Optimization	Available in 1st Iteration
GR_VERD_3	Energy produced (kWh) for residential and commercial customer	VERD	Flexibility Analytics and Consumer-Centric DR Optimization	Available in 1st Iteration
GR_VERD_4	Consumption (KWh) for residential and commercial customer	VERD	Flexibility Analytics and Consumer-Centric DR Optimization	Available in 1st Iteration
GR_VERD_5	Battery SoC (%)for residential and commercial customer	VERD	Flexibility Analytics and Consumer-Centric DR Optimization	Available in 1st Iteration
GR_VERD_6	Battery power (kW) - Inverter for residential and commercial customer	VERD	Flexibility Analytics and Consumer-Centric DR Optimization	Available in 1st Iteration
GR_VERD_7	Battery charging state (enum) - Inverter for residential and	VERD	Flexibility Analytics and Consumer-	Available in 1st Iteration

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	commercial customer		Centric DR Optimization	
GR_VERD_8	IoT - Active Power (kW) for residential customer	VERD	Flexibility Analytics and Consumer-Centric DR Optimization	Available in 1st Iteration
GR_VERD_9	IoT - Reactive Power (kVar) for residential customer	VERD	Flexibility Analytics and Consumer-Centric DR Optimization	Available in 1st Iteration
GR_VERD_10	IoT - Consumed Energy (kWh) for residential and commercial customer	VERD	Flexibility Analytics and Consumer-Centric DR Optimization	Available in 1st Iteration
GR_VERD_11	IoT – interior temperature (°C) for commercial customer	VERD	Flexibility Analytics and Consumer-Centric DR Optimization	Available after M27
GR_VERD_12	IoT – interior humidity (%) for commercial customer	VERD	Flexibility Analytics and Consumer-Centric DR Optimization	Available after M27
GR_VERD_13	IoT – occupancy for commercial customer	VERD	Flexibility Analytics and Consumer-Centric DR Optimization	Available after M27
GR_VERD_14	Energy Demand (kWh) per apartment in the commercial customer's premises	VERD	Flexibility Analytics and Consumer-Centric DR Optimization	Available after M27
GR_VERD_15	HVAC Energy Demand (kWh) for one apartment in the commercial customer's premises	VERD	Flexibility Analytics and Consumer-Centric DR Optimization	Available after M27
GR_HEDNO_4	Flexibility Data	HEDNO, IPTO	Flexibility Analytics and Consumer-Centric DR Optimization	Available in 1st Iteration

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Energy applications

The energy applications that will be used to develop DC5 are introduced in the next table.

Table 29: Energy applications tested within DC5

Energy app name	Components	Input data assets (IDA)	Output data assets (ODA)
Tool - Flexibility Analytics and Consumer-Centric DR Optimization Subcomponent - Aggregator Portfolio Manager	The component in charge of facilitating aggregators to have a clear picture and management of their portfolio's performance, in order to be able to deliver the required flexibility to network operators considering the flexibility characteristics of their customer S5	*from SYNERGY platform to energy app (csv, json, graphs, etc)* Flexibility contracts – IDA 1 – HEDNO (GR_HEDNO_4) IDA 2 - VERD (GR_VERD_1 to 15)	*from the energy app to the SYNERGY platform (csv, json, graphs, etc)* ODA – 1 – S5 DER Flexibility Profile ODA – 2 – S5 Building Level Flexibility Profile ODA – 3 – S5 Flexibility Clusters
Tool - Flexibility Analytics and Consumer-Centric DR Optimization Subcomponent - VPP configuration engine	Provide advanced Decision Support System (DSS) functionalities towards creating ad-hoc dynamic Virtual Power Plants (VPP) considering the type of service requested by the network operator and the flexibility characteristics of its underlying portfolio. The VPP Configuration Engine is able to continuously monitor the performance of the VPP and re-configure on the fly the initial VPP once a flexibility source has unexpectedly withdrawn from the VPP during the evolution of a flexibility provision event.	Flexibility contracts – IDA 1 – HEDNO (GR_HEDNO_4) IDA 2 - VERD (GR_VERD_1 to 15) IDA 3 – HEDNO (GR_HEDNO_1, 2, 4, 5) 3rd Party Flexibility Request - HEDNO, IPTO	ODA – 1 – S5 DER/Building Flexibility Profile ODA – 2 – S5 DER Level Flexibility Profile ODA – 4 – S5 - Portfolio Flexibility Strategies

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	S5		
DR Smart Contract Monitoring, Handling, Settlement and Remuneration Platform Subcomponent – Flexibility Marketplace Search Engine	The DR Smart Contract Monitoring, Handling, Settlement and Remuneration Platform implements all necessary features to allow DER Aggregators and Flexible Asset Managers to come into a common marketplace and negotiate the enrolment of the flexibility assets in different flexibility services through a contractual process. The role of the Flexibility Marketplace Search Engine is to facilitate aggregators to search from a pool about flexibility sources with specific characteristics that fit to their business objectives. On the other hand, the flexibility asset managers will have the opportunity to properly configure the characteristics and parameters of their flexible assets in the marketplace, enabling that way their active participation and collaboration in evolving flexibility-based market schemas. S5	DERs Operational and Energy Parameters - IDA1 – VERD (GR_VERD_2, GR_VERD_5, GR_VERD_6, GR_VERD_7) Smart Device Operational and Energy Parameters - IDA 2 - VERD (GR_VERD_8 to 15)	ODA 1 – DER Flexibility Profiles – S5 ODA 2 – Building level flexibility profiles
DR Smart Contract Monitoring, Handling, Settlement and Remuneration Platform	The role of the Flexibility Contracts Manager is to manage the contractual process among aggregators and flexibility asset managers. S5	Customer Configuration Parameters - VERD	ODA 6 - Information about the contractual agreements among aggregators and flexible asset managers – S5

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Subcomponent – Flexibility Contracts Manager			
DR Smart Contract Monitoring, Handling, Settlement and Remuneration Platform Subcomponent – Flexibility Settlement & Remuneration Engine	The Flexibility Settlement & Remuneration Engine leverages innovative energy baseline techniques - further complemented by adjustment and normalization methods – to enable fair settlement and remuneration of the flexibility assets for participation in flexibility services. S5	ODA 6 - Information about the contractual agreements among aggregators and flexible asset managers – S5 The actual measurement of DER/Building required for the settlement process The flex request triggered by the Aggregator to flexibility asset owner for activation of flexibility	ODA 1 – DER Flexibility Profiles – S5 ODA 2 – Building level flexibility profiles – S5 ODA 7 – Flexibility Settlement Parameters – S5 ODA 8 – Actual flexibility offer – S5 ODA 9 - Time series (history) of baseline energy per each DER of the portfolio – S5
DR Smart Contract Monitoring, Handling, Settlement and Remuneration Platform Subcomponent – Blockchain wallet	The role of the Blockchain Wallet is to act as the user registry and management layer to enable end user's interaction with the blockchain-enabled smart contract monitoring, handling, settlement and remuneration platform. S5	n/a	n/a

Data analytics

The analytics that are expected to be used in DC5 are introduced in the following table.

Table 30: Data analytics used in DC5

Data Analytics name	Description	Input data assets (IDA)	Output data assets (ODA)

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Flexibility Profile Clustering	Apply ML based clustering techniques to extract portfolio clusters on the basis of flexible asset characteristics S5	DERs Operational Characteristics Contract Details Flexibility Profiles	Flexibility Clusters
Building level Flexibility Profiling	Train a specific model to forecast time series of flexibility potential per each smart asset of the building of the portfolio S5	Smart Device Operational and Energy Parameters	Building level Flexibility Profiles
Portfolio Flex Optimization	Develop an optimization algorithm for the optimal placement of flexible assets in 3rd party business requests S5	Flexibility Contract Details 3rd Party Flexibility Request Portfolio Flexibility Clusters DER Flexibility Profiling Building level Flexibility Profiling	Portfolio Flexibility Strategies
DER Flexibility Profiling	Develop an optimization algorithm for the optimal placement of flexible assets in 3rd party business requests S5	DERs Operational and Energy Parameters	DER Flexibility Profiles
Flexibility Aggregation	Simple aggregations of flexibility over time to support visualization of flexibility potential S5	Flexibility Profiles	Aggregate Flexibility Values
Baseline Energy Profiling	Train a specific model to provide baseline estimations of energy consumption/generation S5	History of DER/Building Metering Data	Baseline Energy Profiles

Hardware Components

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The hardware components used to develop DC5 are listed in the following table .

Table 31: Hardware components used in DC5

Hardware component id	Description	Input data assets (IDA)	Output data assets (ODA)
HW 1	Smart meter – VERD	n/a	Metering data from smart meter in VERD's residential and commercial customer's properties .csv
HW 2	PV System – VERD	n/a	Metering data from PV system in VERD's residential and commercial customer's properties .csv
HW 3	Storage System (Inverter) – VERD	n/a	Metering data from storage system in VERD's residential and commercial customer's properties .csv
HW 4	Smart Devices – VERD	n/a	Metering data from smart devices in VERD's residential and commercial customer's properties .csv

<u>Workflow</u>

The following sequential diagram and flow chart depict how the Demo Case will be implemented:

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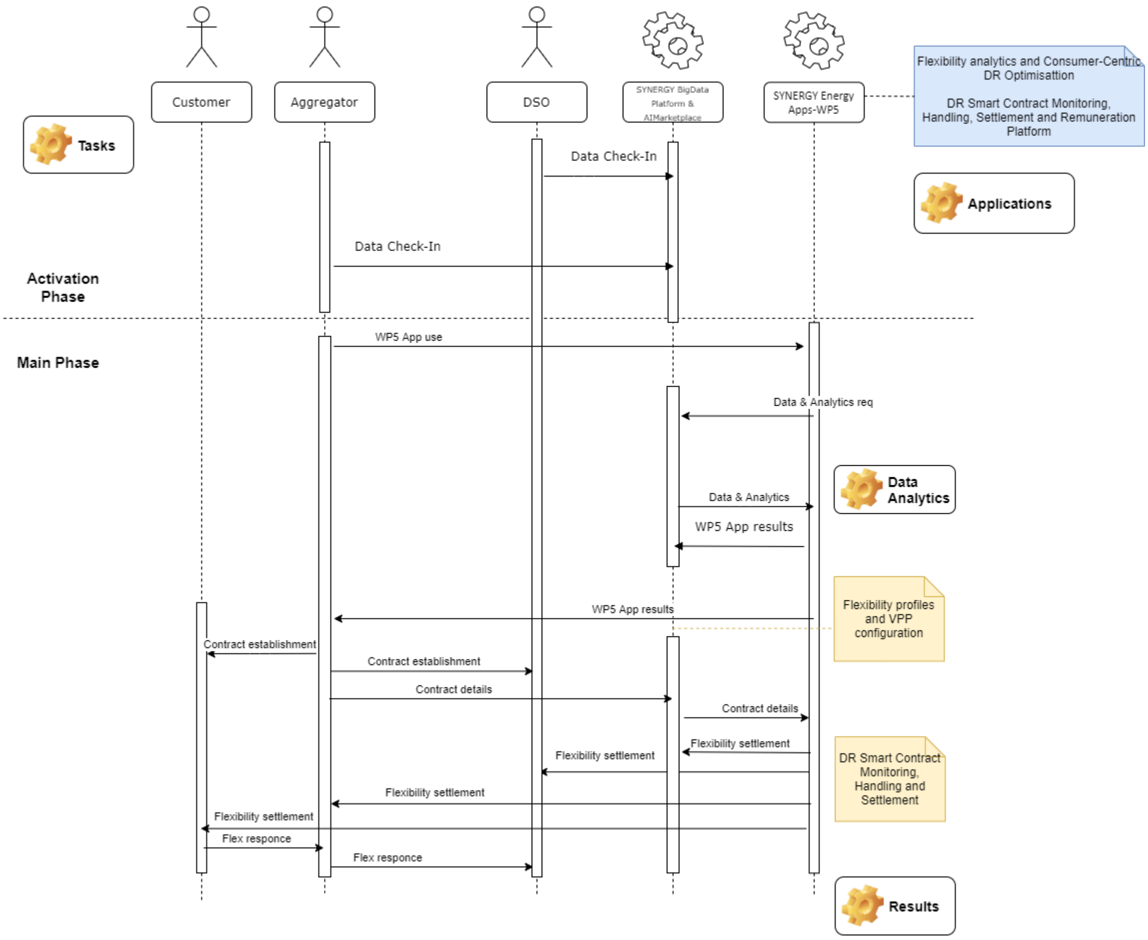

Figure 17:DC 5 sequential diagram

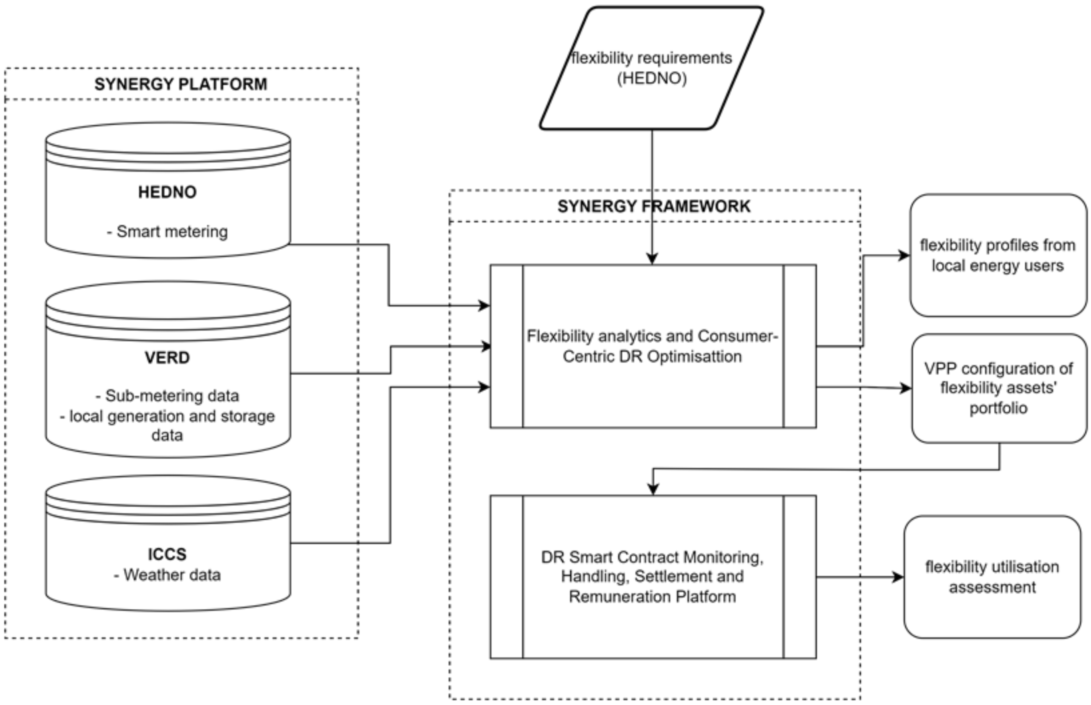

Figure 18 Flow Chart of DC 5

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The Demo Case will be validated as follows, during both Demo runs:

First Demo run:

Validation Scenario 1: Data transmitted correctly to the SYNERGY platform

Preliminary phase:
All data is pre-processed by the providing partner.
Activation phase:
Data is uploaded to the platform
Main phase:
Data configuration and mapping is performed successfully through appropriately configured data check-in jobs
Results:
The SYNERGY platform should contain the data for all the declared assets.

Validation Scenario 2: Data received correctly from the Flexibility Analytics and Consumer-Centric DR Optimization Application through the SYNERGY Platform.

Preliminary phase:
All data is pre-processed by the Data Ingestion Services of the platform.
Activation phase:
The Flexibility Analytics and Consumer-Centric DR Optimization Application is invoked.
Main phase:
The Flexibility Analytics and Consumer-Centric DR Optimization Application should invoke the platform's API to obtain all the necessary data.
Results:
The Flexibility Analytics and Consumer-Centric DR Optimization Application should contain the data for all the declared assets.

First and Second Demo run:

Validation Scenario 3: Produce flexibility profiles at different spatio-temporal granularity

Preliminary phase: All data is obtained by the Flexibility Analytics and Consumer-Centric DR Optimization Application
Activation phase:
The Flexibility Analytics and Consumer-Centric DR Optimization Application is triggered by the aggregator
Main phase:
The Flexibility Analytics and Consumer-Centric DR Optimization Application takes into account all inputs and runs the analytics to produce flexibility profiles in the spatio-temporal granularities requested by the user
Results:
Flexibility profiles are produced in different spatio-temporal granularity

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Validation Scenario 4: Produce VPP composition and validate with local DSO and TSO that the composition matches the flexibility requirements

Preliminary phase: All data is obtained by the VPP configuration engine
Activation phase:
The VPP configuration Engine is triggered by the aggregator
Main phase:
The VPP configuration Engine takes into account all inputs and runs the analytics to produces a VPP composition of the system. The composition is then validated against DSO's and TSO's flexibility requirements
Results:
An optimum VPP composition is produced.

5.1.5.2 Impact KPIs

The KPIs that will be assessed in this demo case are:

- Flexibility Forecasting Accuracy
- Flexibility on offer (as a % of energy consumption)
- Flexibility on capacity
- Actual flexibility availability
- Flexibility Request
- Flexibility Activation
- Flexibility Override
- Actual flexibility on contract
- Flexibility request on contract
- Revenue on contract
- Penalty on contract
- Profit on contract

5.1.5.3 Preliminary evaluation plan

The preliminary evaluation plan, during the first demo run, will consist mainly of making sure that all the applications and components developed, along with the corresponding analytics and algorithms, are working as intended and can provide reliable and feasible results. Furthermore, the data needed and uploaded to the SYNERGY platform must be adequately provided and validated in order to ensure that the necessary requirements for the execution of the demo case are met. After these pre-conditions are met, during the second demo run, the developed applications will be evaluated as a

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whole, in order to ensure that all of SYNERGY's goals are met successfully. For this demo case, smart contracts will need to be established between the involved parties.

5.1.6 Demo Case 6: Local Flexibility Sharing for Self-Consumption Optimization at Local Community Level

5.1.6.1 Validation Scenario

Description

Demo case 6, Local Flexibility Sharing for Self-Consumption Optimization at Local Community Level, will validate the Building - and District-level optimisation tools within the SYNERGY platform that will allow local flexibility sources/ prosumers to engage for the establishment of local energy communities towards the realization of self-consumption maximization and energy cost reduction goals.

Energy consumption/ metering data, generation data and energy storage information, along with IoT data from prosumer premises will be shared with VERD for further analysis and extraction of local flexibility capabilities at different spatio-temporal granularity. Consequently, the resulting flexibility profiles will be utilized by VERD for properly matching demand and supply and improving their synchronization at the local level, while considering the significant flexibility that can be offered by local storage (storage of excess electricity during high RES-output periods and utilization at periods of low generation). In this way VERD will enable the maximization of local self-consumption and reduction of energy costs at local community level.

The scope of this demo is to determine the common benefits of the self-consumption optimization strategies and transparently and objectively share them among local community members.

The following validation scenarios can be tested in order to make sure that the outcome is as expected:

- Validation Scenario 1: Data transmitted correctly to the SYNERGY Platform
- Validation Scenario 2: Data received correctly from the BL-EPOM Application through the SYNERGY Platform.
- Validation Scenario 3: Data received correctly from the DL-EPOM Application through the SYNERGY Platform.
- Validation Scenario 4: Extraction of local flexibility capabilities at different spatio-temporal granularity at a building level using the BL-EPOM tool

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- Validation Scenario 5: Matching of demand and supply in order to improve their synchronization at the local level and enable the maximization of local self-consumption and reduction of energy costs at local community level.
- Validation Scenario 6: Establishment of smart contracts and shared benefits

Objectives

Demo case Objectives:

- Target 1: Energy consumption minimisation for local energy prosumers
- Target 2: Quantification of the energy cost minimisation for local energy prosumers using energy tariffs

Objectives of the validation scenarios:

- Objective 1: Data is successfully and accurately uploaded to the SYNERGY platform.
- Objective 2: Data is successfully and accurately transferred to the BL- and DL-EPOM application.
- Objective 3: Aggregate information from prosumers and validate the BL- and DL-EPOM application.
- Objective 4: Enable the verification of the contribution of each individual prosumer in the realization of common benefits and accordingly distribute benefits (energy cost reductions) to the involved parties.

Stakeholders

Stakeholders involved are:

- VERD: Aggregator/ESCO, Data Owner, Provider, Broker and Consumer as well as Data Management and Services provider. This is the sole stakeholder of this DC.

Use cases

- UC_6_6: Intelligent human-centric control
- UC_7_5: Energy Performance optimisation at building level (CIRCE)
- UC_7_6: Energy Performance optimisation at district level (CIRCE)

Available Data Assets

The data assets that will be used to develop DC 6 are introduced in the following table.

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Table 32: Available data assets for DC6

Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform
GR_VERD_1	Energy imported from the Grid (kWh) for commercial customer	VERD	BL-EPOM DL-EPOM	Data available on M27
GR_VERD_2	Energy exported to the Grid (kWh) for commercial customer	VERD	BL-EPOM DL-EPOM	Data available on M27
GR_VERD_3	Energy produced (kWh) for commercial customer	VERD	BL-EPOM DL-EPOM	Data available on M27
GR_VERD_4	Consumption (KWh) for commercial customer	VERD	BL-EPOM DL-EPOM	Data available on M27
GR_VERD_5	Battery SoC (%)for commercial customer	VERD	BL-EPOM DL-EPOM	Data available on M27
GR_VERD_6	Battery power (kW) - Inverter for commercial customer	VERD	BL-EPOM DL-EPOM	Data available on M27
GR_VERD_7	Battery charging state (enum) - Inverter for commercial customer	VERD	BL-EPOM DL-EPOM	Data available on M27
GR_VERD_10	IoT - Consumed Energy (kWh) for commercial customer	VERD	Flexibility Analytics and Consumer-Centric DR Optimization	Available in 1st Iteration
GR_VERD_11	IoT – interior temperature (°C) for commercial customer	VERD	Flexibility Analytics and Consumer-Centric DR Optimization	Available after M27

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GR_VERD_12	IoT – interior humidity (%) for commercial customer	VERD	Flexibility Analytics and Consumer-Centric DR Optimization	Available after M27
GR_VERD_13	IoT – occupancy for commercial customer	VERD	Flexibility Analytics and Consumer-Centric DR Optimization	Available after M27
GR_VERD_14	Energy Demand (kWh) per apartment in the commercial customer's premises	VERD	Flexibility Analytics and Consumer-Centric DR Optimization	Available after M27
GR_VERD_15	HVAC Energy Demand (kWh) for one apartment in the commercial customer's premises	VERD	Flexibility Analytics and Consumer-Centric DR Optimization	Available after M27

Energy applications

The energy applications that will be tested within DC6 are described in Table 33.

Table 33: Energy applications to be used in DC6

Energy app name	Components	Input data assets (IDA)	Output data assets (ODA)
BL_EPOM	The module supports facility managers, in presence of flexible devices and systems, to design appropriate flexibility control strategies to maximize self-consumption and reduce energy costs for independent buildings and groups of buildings It can be summarised as the calculation of the operation profile of manageable systems that maximize self-consumption and reduce energy costs according to the expected building energy demand and generation and its systems state.	IDA 1 - PV generator characteristics – VERD IDA 2 - Storage system characteristics – VERD IDA 3 - Grid connection	ODA 1 - Short-term PV forecasts – CIRCE ODA 2 - Energy prices forecast – CIRCE ODA 3 - Short-term weather forecasts – CIRCE ODA 4 - Short-term building forecasts – CIRCE ODA 5 - Optimal operation setpoints – CIRCE

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	CIRCE	characteristics – VERD IDA 4 - Cost per consumed power (€/kW*year) – VERD IDA 5 -Temperature set-point for HVAC - VERD IDA 6 - Storage system data – VERD IDA 7 - Grid connection availability - VERD IDA 8 - PV generators availability - VERD IDA 9 - Weather data IDA 10 - Building internal temperature and building data - VERD	
DL_EPOM	The module supports facility managers, in presence of flexible devices and systems, to design appropriate flexibility control strategies to maximize self-consumption and reduce energy costs for independent buildings and groups of buildings It can be summarised as the calculation of the operation profile of manageable systems that maximize self-consumption and reduce energy costs according to the expected district energy demand and generation and its systems state. CIRCE	IDA 1 - PV generator characteristics – VERD IDA 2 - Storage system characteristics – VERD IDA 3 - Grid connection	ODA 1 - Short-term PV forecasts – CIRCE ODA 2 - Energy prices forecast – CIRCE ODA 3 - Short-term weather forecasts – CIRCE ODA 4 - Short-term building forecasts – CIRCE ODA 5 - Optimal operation setpoints – CIRCE

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		characteristics – VERD IDA 4 - Cost per consumed power (€/kW*year) – VERD IDA 5 -Temperature set-point for HVAC - VERD IDA 6 - Storage system data – VERD IDA 7 - Grid connection availability - VERD IDA 8 - PV generators availability - VERD IDA 9 - Weather data IDA 10 - Building internal temperature and building data – VERD IDA 11 - Electric grid between building characteristics – VERD	
DR Smart Contract Monitoring, Handling, Settlement and Remuneration Platform Subcomponent – Flexibility Marketplace Search Engine	The DR Smart Contract Monitoring, Handling, Settlement and Remuneration Platform implements all necessary features to allow DER Aggregators and Flexible Asset Managers to come into a common marketplace and negotiate the enrolment of the flexibility assets in different flexibility services through a contractual process. The role of the Flexibility Marketplace Search Engine is to facilitate aggregators to search from a pool about flexibility sources with specific characteristics that fit to their business objectives. On the other hand, the flexibility asset managers will have the opportunity to properly configure the characteristics and parameters of their flexible assets in the	DERs Operational and Energy Parameters - IDA1 – VERD (GR_VERD_2, GR_VERD_5, GR_VERD_6, GR_VERD_7) Smart Device Operational and Energy Parameters - IDA 2 - VERD (GR_VERD_8 to 15)	ODA 1 – DER Flexibility Profiles – S5 ODA 2 – Building level flexibility profiles

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	marketplace, enabling that way their active participation and collaboration in evolving flexibility-based market schemas. S5		
DR Smart Contract Monitoring, Handling, Settlement and Remuneration Platform Subcomponent – Flexibility Contracts Manager	The role of the Flexibility Contracts Manager is to manage the contractual process among aggregators and flexibility asset managers. S5	Customer Configuration Parameters - VERD	ODA 6 - Information about the contractual agreements among aggregators and flexible asset managers – S5
DR Smart Contract Monitoring, Handling, Settlement and Remuneration Platform Subcomponent – Flexibility Settlement & Remuneration Engine	The Flexibility Settlement & Remuneration Engine leverages innovative energy baseline techniques - further complemented by adjustment and normalization methods –to enable fair settlement and remuneration of the flexibility assets for participation in flexibility services. S5	ODA 6 - Information about the contractual agreements among aggregators and flexible asset managers – S5 The actual measurement of DER/Building required for the settlement process The flex request triggered by the Aggregator to flexibility asset owner for activation of flexibility	ODA 1 – DER Flexibility Profiles – S5 ODA 2 – Building level flexibility profiles – S5 ODA 7 – Flexibility Settlement Parameters – S5 ODA 8 – Actual flexibility offer – S5 ODA 9 - Time series (history) of baseline energy per each DER of the portfolio – S5
DR Smart Contract Monitoring, Handling, Settlement and Remuneration Platform Subcomponent – Blockchain wallet	The role of the Blockchain Wallet is to act as the user registry and management layer to enable end user's interaction with the blockchain-enabled smart contract monitoring, handling, settlement and remuneration platform. S5	n/a	n/a

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Data analytics

The analytics that will be used to develop DC6 are introduced in the following table.

Table 34: Data analytics to be used in DC6

Data Analytics name	Algorithm	Input data assets (IDA)	Output data assets (ODA)
Build short-term Portfolio-level HVAC demand Energy forecast model	Train a specific model to forecast HVAC demand CIRCE	Weather data Building internal temperature - VERD Building location (latitude and longitude) HVAC consumption - VERD Building occupancy - VERD	HVAC demand model - CIRCE
Building level Flexibility Profiling	Train a specific model to forecast time series of flexibility potential per each smart asset of the building of the portfolio S5	Smart Device Operational and Energy Parameters	Building level Flexibility Profiles
DER Flexibility Profiling	Develop an optimization algorithm for the optimal placement of flexible assets in 3rd party business requests S5	DERs Operational and Energy Parameters	DER Flexibility Profiles
Flexibility Aggregation	Simple aggregations of flexibility over time to support visualization of flexibility potential S5	Flexibility Profiles	Aggregate Flexibility Values
Baseline Energy Profiling	Train a specific model to provide baseline estimations of energy	History of DER/Building Metering Data	Baseline Energy Profiles

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	consumption/generation S5		

Hardware Components

The hardware components that will be used to develop DC6 are listed in the following table

Table 35: Hardware components to be used in DC6

Hardware component id	Description	Input data assets (IDA)	Output data assets (ODA)
HW 1	Smart meter – VERD	n/a	Metering data from smart meter in VERD’s commercial customer’s property json
HW 2	PV System – VERD	n/a	Metering data from PV system in VERD’s commercial customer’s property Json
HW 3	Storage System (Inverter) – VERD	n/a	Metering data from storage system in VERD’s commercial customer’s property json
HW 4	Smart Devices – VERD	n/a	Metering data from smart devices in VERD’s commercial customer’s property json

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Workflow

The following sequential diagram and flow chart depict how the Demo Case will be implemented:

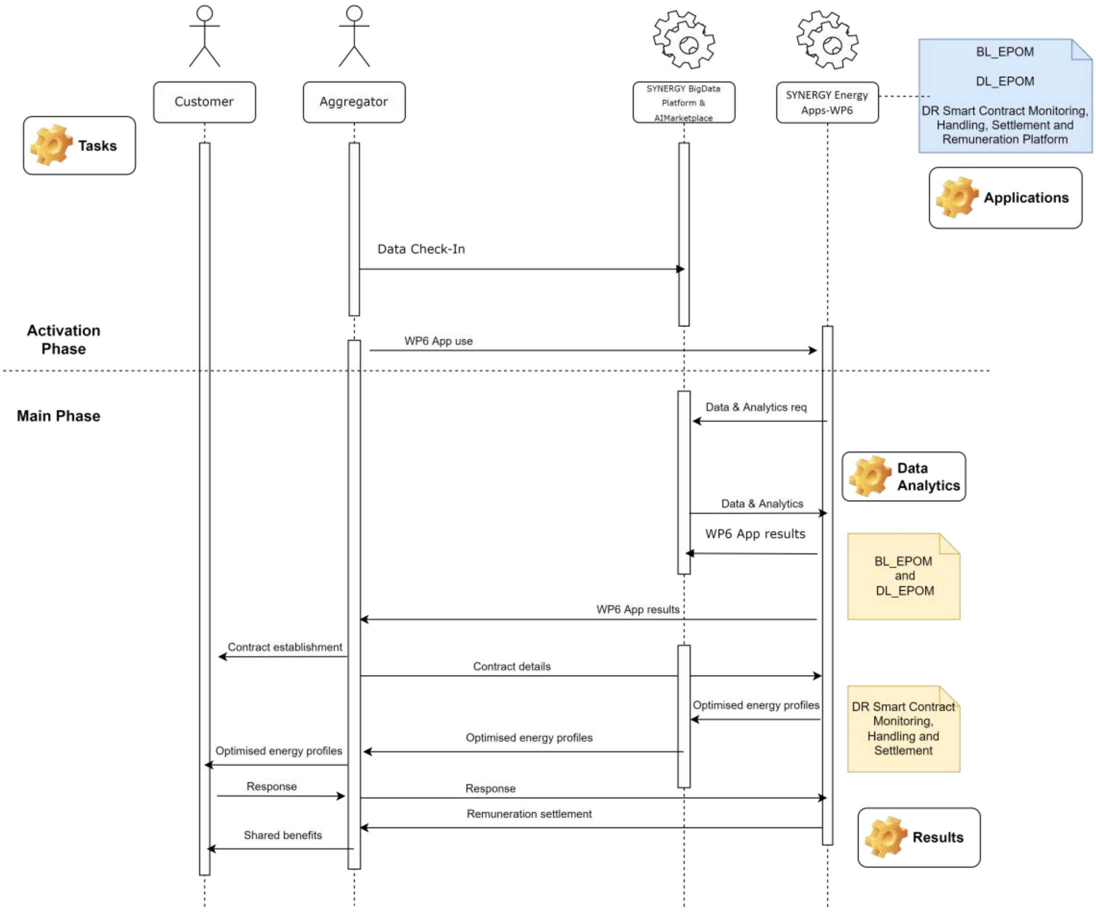

Figure 19: DC6 sequential diagram

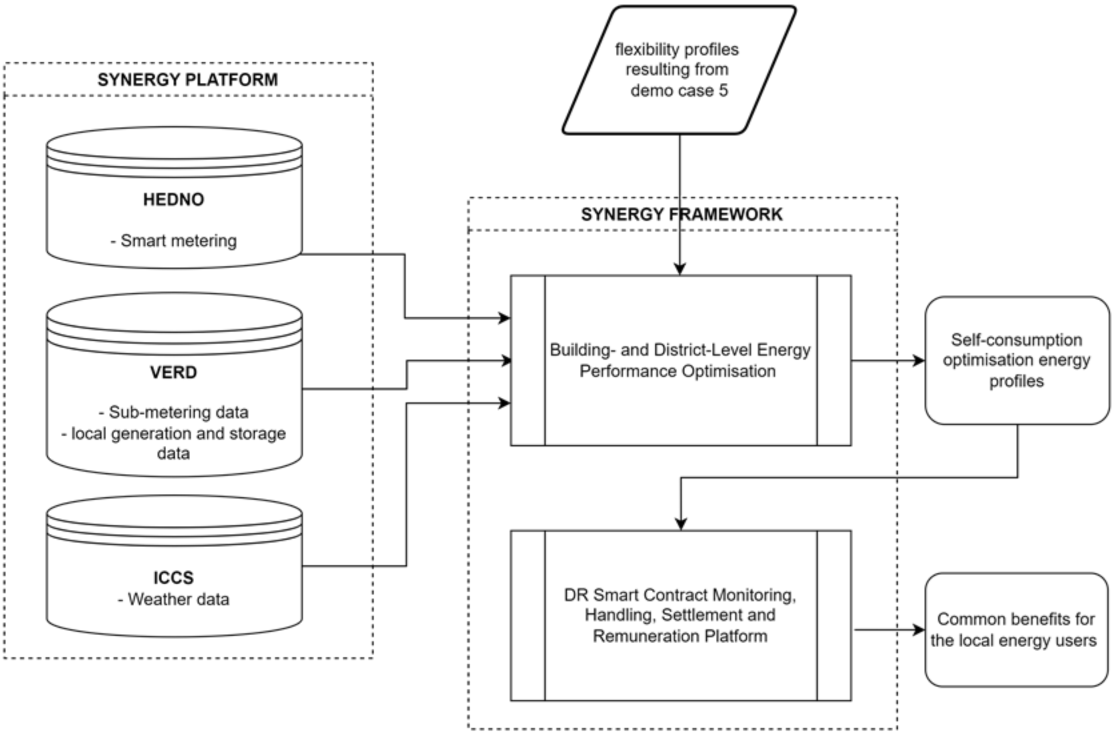

Figure 20 : Flow Chart of DC 6

The Demo Case will be validated as follows, during both Demo runs:

First Demo run:

Validation Scenario 1: Data transmitted correctly to the SYNERGY platform

Preliminary phase:
All data is pre-processed by the providing partner.
Activation phase:
Data is uploaded to the platform
Main phase:
Data configuration and mapping is performed successfully
Results:
SYNERGY platform should contain the data for all the declared assets.

Validation Scenario 2: Data received correctly from the BL-EPOM Application through the SYNERGY Platform.

Preliminary phase:
All data is pre-processed by the Data Ingestion Services of the platform.
Activation phase:
The BL-EPOM Application is invoked.
Main phase:

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The BL-EPOM Application should invoke the platform's API in order to obtain all the necessary data.

Results:

The BL-EPOM Application should contain the data for all the declared assets.

First and Second Demo run:

Validation Scenario 3: Data received correctly from the DL-EPOM Application through the SYNERGY Platform.

Preliminary phase:

All data is pre-processed by the Data Ingestion Services of the platform.

Activation phase:

The DL-EPOM Application is invoked.

Main phase:

The DL-EPOM Application should invoke the platform's API in order to obtain all the necessary data.

Results:

The DL-EPOM Application should contain the data for all the declared assets.

Validation Scenario 4: Extraction of local flexibility capabilities at different spatio-temporal granularity at a building level using the BL-EPOM application

Preliminary phase:

All data is obtained by the BL-EPOM application

Activation phase:

The BL-EPOM application is triggered by the aggregator

Main phase:

The BL-EPOM application takes into account all inputs and runs the analytics to produce flexibility profiles in the spatio-temporal granularities requested by the user (at building level)

Results:

Flexibility profiles are produced in different spatio-temporal granularity and are made available to the user

Validation Scenario 5: Matching of demand and supply in order to improve their synchronization at the local level and enable the maximization of local self-consumption and reduction of energy costs at local community level.

Preliminary phase:

Demand, supply and flexibility profiles resulting from BL-EPOM application are loaded into the DL-EPOM application

Activation phase:

The DL-EPOM application is triggered by the aggregator.

Main phase:

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The DL-EPOM application takes into account all inputs and runs the analytics to produce the optimum configuration of resources that would maximise local self-consumption and energy cost savings at local community level

Results:

Optimum operation setpoints are produced to maximise local self-consumption and reduce energy costs at local community level.

Validation Scenario 6: Establishment of smart contracts and shared benefits

Preliminary phase:

Optimal control setpoints and flexibility profiles are loaded into the DR Smart Contract Monitoring, Handling and Settlement application

Activation phase:

The DR Smart Contract Monitoring, Handling and Settlement application is triggered by the aggregator.

Main phase:

The DR Smart Contract Monitoring, Handling and Settlement application takes into account all inputs along with the smart contract details signed by all parties and runs the analytics in order to calculate the benefits of the involved parties

Results:

Shared benefits between the involved parties are established and contracts are activated

5.1.6.2 Impact KPIs

The KPIs that will be assessed in this demo case are:

- Peak load demand reduction
- Self-consumption ratio (for the consumer/aggregator)
- Cost savings for consumers and other stakeholders
- Actual flexibility on contract
- Flexibility request on contract
- Revenue on contract
- Penalty on contract
- Profit on contract

5.1.6.3 Preliminary evaluation plan

The preliminary evaluation plan, during the first demo run, will consist mainly of making sure that all the applications and components developed, along with the corresponding analytics and algorithms, are working as intended and can provide reliable and feasible results. Furthermore, the data needed

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and uploaded to the SYNERGY platform must be adequately provided and validated in order to ensure that the necessary requirements for the execution of the demo case are met.

After these pre-conditions are met, during the second demo run, the developed applications will be evaluated as a whole, in order to ensure that all of SYNERGY's goals are met successfully. For this demo case, smart contracts will need to be established between the involved parties in order to ensure that the benefits are shared between them.

5.2 Evaluation in Spanish Demo

5.2.1 Demo Case 7: Enhanced PV Plant Asset Management

5.2.1.1 Validation Scenario

Description

Traditional performance Monitoring PV plants will be improved by strategically monitoring a set of KPIs which allow the enhancement of the performance and operation of PV assets. One of the results of this demo case will be a set of KPIs presenting important indexes about the health and status of the installation. This information will be additionally used for validating new approaches of predictive maintenance. The analysis of failures and reliability indexes will be analysed, presenting potential impacts of a single component failure to operation of the whole installation. This demo case will be led and performed by COBRA in one of its plants, as the solo partner involved on it. It will be demonstrated in one of the plants owned and operated by COBRA, using the operational data of the plant at different levels. Firstly, the data will be remotely collected; then it will be processed, and the results will be communicated periodically to the operation and maintenance team identifying potential issues that should be improved, as well as early fault detection, in order to avoid dramatical energy losses or plant interruption. Finally, the energy yielded will be quantified, including also how it can affect the economic and energy KPIs.

Objectives

The main targets sought with this demo case are outlined below:

- Objective 1: Identify strategic operational KPIs which represent the correct operation of PV plants.

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- Objective 2: Early fault detection for energy losses minimisation due to operational failures of equipment or malfunctioning.
- Objective 3: Predictive maintenance scheduling to avoid failures with critical impact on the power production.
- Objective 4: Levelised Cost of Energy (LCoE) reduction through an optimal O&M management and reduction of energy losses due to small faults preciously not identified.

Stakeholders

Stakeholder 1: **COBRA** will act as PV Asset owner and RES Operator. Its role will be both, to analyse the operational information coming from the PV plant, analyse the input data and assess the KPIs defined in the demo case.

Use cases

The use cases involved in this demo case are:

- Use case 5_5: Performance Monitoring of PV Plants status and assets' health.
- Use case 5_6: Predictive Maintenance of PV Assets.

Available Data Assets

The available datasets at the PV plant have been combined, grouping datasets with similar type of information (i.e. inverter currents, inverter voltages, energy produced, etc.), in order to simplify the data upload and retrieval to and from the SYNERGY platform. Hence, the main datasets used are:

Table 36: Available Data Assets for DC7

Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform
DC7_DN_1	DC and AC currents and voltages at inverter level and at combiner box level; Frequency; Power Factor	COBRA	Performance Monitoring/Forecasting and Predictive Maintenance	Available is 1st iteration
DC7_DN_2	Operational data (Power at inverter, at power station, Frequency, Reactive Power, , etc.)	COBRA	Performance Monitoring/Forecasting and Predictive Maintenance	Available in 1st iteration

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DC7_DN_3	Weather data (Ambient temperature, irradiance, cell temperature, wind, horizontal radiation, humidity, etc.)	COBRA	Performance Monitoring/Forecasting and Predictive Maintenance	Available in 1st iteration
DC7_DN_4	O&M fault reports	COBRA	Performance Monitoring/Forecasting and Predictive Maintenance	Available in 1st iteration

Energy applications

The energy applications that will be used to develop DC7 are introduced in the next table.

Table 37: Energy applications to be used in DC7

Energy app name	Components	Input data assets (IDA)	Output data assets (ODA)
Performance Monitoring/Forecasting and Predictive Maintenance	A tool that allows PV plant operators to visualise the operation of the plant, displaying strategic KPIs of the plant at inverter level. Moreover, the app identifies anomalies during the operation and gives insights about potential risks of failures in the short-term. - Responsible Partner: COBRA	IDA 1- COBRA (DC7_DN_1, 2, 3)	Advanced Dashboard showing strategic KPIs newly defined: ODA 1- COBRA Probability of anomaly at different levels: ODA 2- COBRA

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Data analytics

The analytics that are expected to be used for the implementation of DC7 are introduced in Table 38. Data analytics will be all executed in the SYNERGY Platform.

Table 38: Data analytics to be used within DC7

Data Analytics name	Input data assets (IDA)	Output data assets (ODA)
Operational and strategic KPI calculations	*IDA 1- COBRA (DC7_DN_1, 2, 3)*	*Advanced Dashboard showing strategic KPIs newly defined: ODA 1- COBRA*
Anomaly/outlier detection in the performance of grid assets	*IDA 1- COBRA (DC7_DN_1, 2, 3)*	*Probability of anomaly at different levels: ODA 2- COBRA*
Clustering of malfunctions/inefficiencies at generation asset level	*IDA 1- COBRA (DC7_DN_1, 2, 3)*	*Type of anomaly (i.e. inverter): ODA 3- COBRA*
Prediction of anomalies	*IDA 1- COBRA (DC7_DN_1, 2, 3)*	*Probability of anomaly at different levels in the short-term: ODA 4 - COBRA*

Hardware Components

The hardware components used for the implementation of DC7are listed in **Error! Reference source not found.**.

Table 39: Hardware components for DC7

Hardware component id	Description	Input data assets (IDA)	Output data assets (ODA)
HW 1	PV Plants SCADA		PV operational data and climatic data from the SCADA of the plant (power, currents, voltages, irradiance, temperature, etc.)

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Workflow

The workflows to be followed for DC7 will be the same for both demo runs. They consist of three main phases: a preliminary phase in which the procedures and collection of data will be carried out; an activation phase, where the apps to be tested will be implemented at the site; and the main phase, where the app will be running and monitored, in order to assess the benefits of the app.

Preliminary phase: Definition of the different procedures of monitoring and maintenance to be tracked and implemented at the plant. An internal protocol to implement the information of the SCADA in the SYNERGY platform will be defined, in order to check whether the data will be periodically uploaded or the SCADA will be directly connected to the SYNERGY platform. The operational data of the existing situation before the demonstration will also be collected during this first stage, gathering and assessing information related to OPEX and LCoE under the existing O&M strategies.

Activation phase: This phase will be related to the start-up of the different procedures defined in the first phase, as well as the exhaustive monitoring and tracking of the strategic KPIs and deployment of the predictive maintenance actions output from the tool. The energy app for RES Operators and Aggregators will be used, more specifically the "Enhanced Performance Monitoring", responsible of providing a visual status of the plant operation, and the "Fault Occurrence Inspector and Maintenance Optimiser", which will identify potential failures at different levels.

Main phase: This phase will be related to the assessment of the KPIs and the predictive maintenance strategies implemented at the plant, estimating the reduction of energy losses as well as the evaluation of the LCoE. The main KPIs linked to this demo case will be analysed, reporting the main achievements, and how a strategic monitoring of a PV assets as well as the predictive maintenance routine can improve the benefits during the operation.

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The following sequential diagram and flow chart depict how the Demo Case will be implemented:

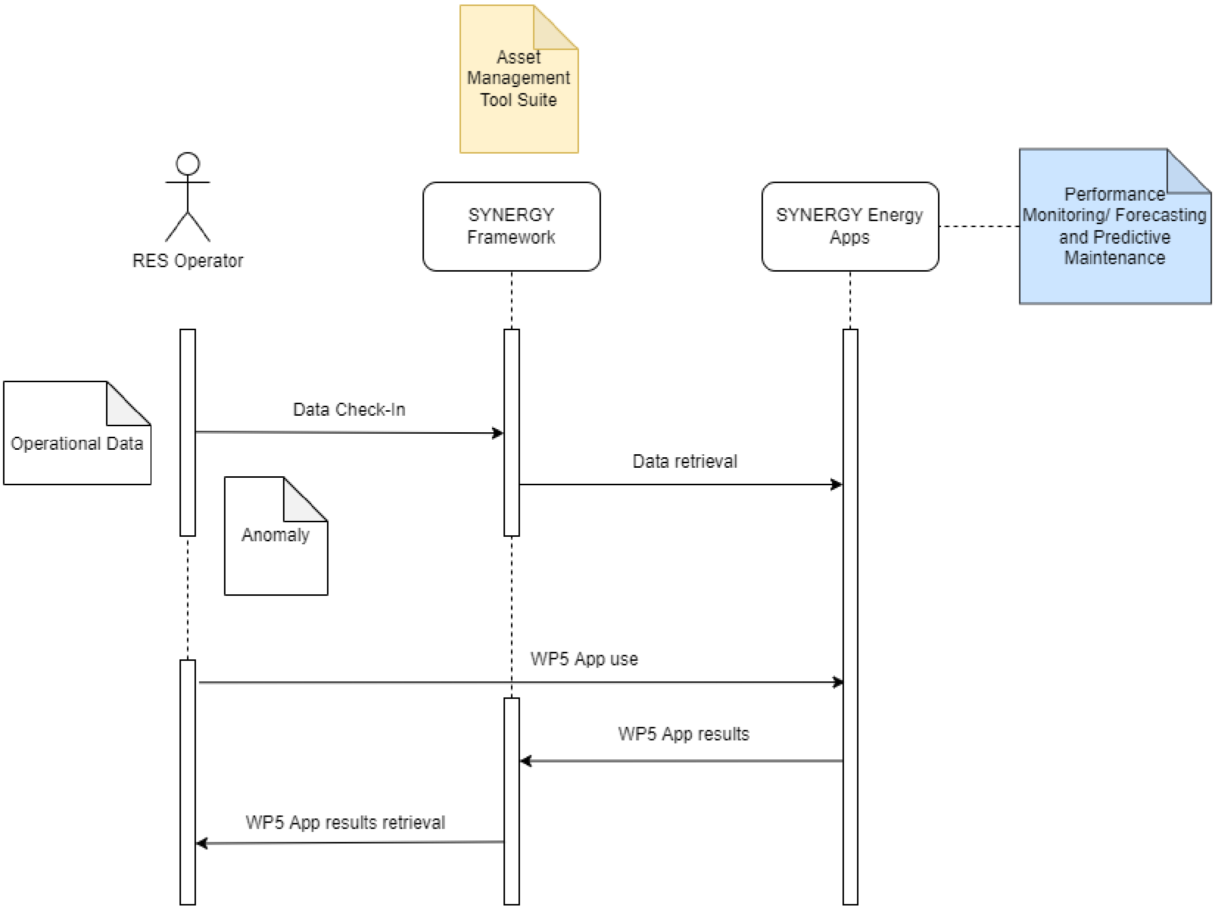

Figure 21: DC7 sequential diagram

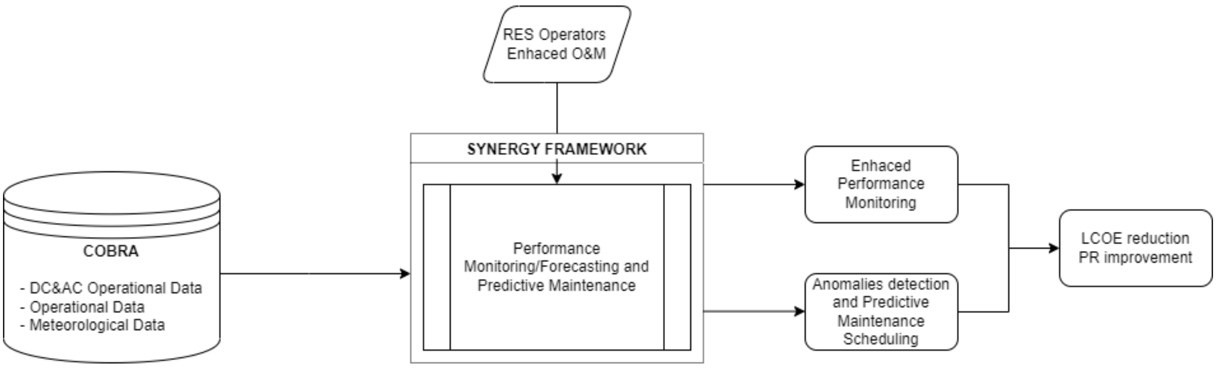

Figure 22:DC7 workflow flowchart

5.2.1.2 Impact KPIs

The main KPIs that will be assessed in demo case 7 are:

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- PV Performance Ratio (PR): It will provide an indicative figure of how efficiently the PV plant is operating.
- Levelised Cost of Energy (LCoE): It will help to quantify the improvements that the app Performance Monitoring/Forecasting and Predictive Maintenance has led to in terms of energy losses reduction.

5.2.1.3 Preliminary Evaluation Plan

The evaluation will be centred on the evaluation of the two KPIs aforementioned, and the comparison with the values considered during the asset feasibility assessment phase, and with the values of the KPIs estimated after several years of operation. The results will highlight the benefits associated to the innovations and tools developed within the SYNERGY project and the main advantages of using the SYNERGY platform.

Firstly, the information related to the KPIs, considered before implementation of the SYNERGY innovations will be collected. This will require of a continuous communication of the team with the O&M department at the PV plant, as well as with the management team, responsible of the economic indexes analysis and decision making affecting the KPIs considered on a regular basis.

Secondly, the results after applying the innovations and tools required in this demo case will be calculated. The enhancement on the energy generation due to reduction of energy losses due to malfunctioning or anomalies will be measured and compared to the revenues obtained under normal operation.

Finally, the improvements on the KPIs will be estimated, thus measuring the benefits to which the performance monitoring and predictive maintenance tool would lead. This should result in an increase of the energy generation due to the strategic monitoring of the plant operation and the early detection of anomalies and predictive maintenance strategies.

This sequence will be followed in both demo runs.

5.2.2 Demo Case 8: Advanced RES Forecasting for improved market positioning and optimized flexibility activation for the provision of services to network operators

5.2.2.1 Validation Scenario

Description

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

This demo case will demonstrate the significant benefits that can be achieved through data sharing and data exchanges between electricity sector stakeholders. Advanced forecasting analytics will fuse and analyse COBRA's in-plant SCADA, with local and regional weather data to provide more accurate power forecasts. Such forecasting will feed into the flexibility segmentation, classification and clustering tool used by URBENER, enabling the further analysis of the flexibility that can be provided through curtailing the operation of the PV plant of COBRA. Through this data sharing approach, COBRA will gain further insights on the flexibility they can provide to overlay energy markets (balancing, ancillary services), while URBENER will obtain access to huge flexibility sources and will act as the facilitator for the participation of such flexibility sources to energy markets.

Objectives

The main targets sought with this demo case are outlined below:

- Objective 1: Increase the RES Operators revenues due to an optimal energy market positioning.
- Objective 2: Reduce the risk investment through an optimal positioning of the asset in the energy markets, maximising the revenues and hence decreasing return of the investment.
- Objective 3: Achieve accurate power forecasts in the short-term for large PV plants.

Stakeholders

Stakeholder 1: **COBRA** will act as PV Asset owner and RES Operator. Its role will be both, to analyse the operational information coming from the PV plant, analyse the input data and assess the KPIs defined in the demo case.

- Stakeholder 2: **URBENER** will act as Energy Company, specialised in energy markets management and positioning. Its role will be to analyse and define the amount of energy drop to each energy market, seeking the revenues maximisation.

Use cases

The use cases involved in this demo case are:

- Use case 5_10: Optimised energy bidding and output sharing in wholesale markets.

Available Data Assets

The data assets that will be used to develop DC 8 are introduced in the following table.

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

Table 40: Available Data Assets for DC8

Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform
DC8_DN_1	Assets coordinates	COBRA	Performance Monitoring/Forecasting and Predictive Maintenance	Available
DC8_DN_2	Operational data (Peak power)	COBRA	Performance Monitoring/Forecasting and Predictive Maintenance	Available
DC8_DN_3	Weather and Production forecasting	COBRA	Performance Monitoring Forecasting and Predictive Maintenance	Available
DC8_DN_4	Electricity Market forecasting	URBENER	Portfolio Analytics and Management Application	Available

<u>Energy applications</u>

This section includes a short description of each energy application, input/output data from/to SYNERGY platform to/from energy application and data exchanged (download/upload) between energy application and involved stakeholders.

Table 41: Energy Applications for DC8

Energy app name	Components	Input data assets (IDA)	Output data assets (ODA)
Performance Monitoring/Forecasting and Predictive Maintenance	A tool that allows PV plant operators to predict the energy generation in	IDA 1: DC8_DN_1 – COBRA IDA 2: DC8_DN_2 - COBRA IDA 3: DC8_DN_3 - COBRA	ODA 1: 48 hours ahead power forecasting

	the short term. - Responsible Partner: COBRA		
Portfolio Analytics and Management Application	Day-ahead portfolio exported energy forecast - Responsible Partner: URBENER	IDA 4: DC8_DN_4 - URBENER	ODA 2- Optimal energy market positioning and revenues forecast.

Data analytics

The analytics that are expected to be used for the implementation of DC8 are introduced in the following table. Data analytics are executed in the SYNERGY Platform

Table 42: Data analytics for DC8

Data Analytics name	Input data assets (IDA)	Output data assets (ODA)
Weather forecasting	IDA 1: Open Access	ODA 1: 48 hours ahead weather forecasting
Short-Term Energy Generation (24-48 hours)	IDA 2: DC8_DN_1 – COBRA IDA 3: DC8_DN_2 - COBRA IDA 4: DC8_DN_3 - COBRA	ODA 2: 48 hours ahead power forecasting
Day-ahead portfolio exported energy forecast	IDA 4: DC8_DN_4 - URBENER	ODA 2- Optimal energy market positioning and revenues forecast.

Hardware Components

The demo case does not require of any of any hardware component. It will use input data defined by the user (i.e. peak power of the PV plant) and open source data (i.e. weather forecast, market prices).

Workflow

The workflows to be followed for DC8 will be the same for both demo runs. They consist of three main phases: a preliminary phase in which the procedures and collection of data will be carried out; an activation phase, where the apps to be tested will be implemented at the site; and the main phase, where the app will be running and monitored, in order to assess the benefits of the app.

Preliminary phase: Firstly, the input information of the specific plant used as demonstrator will be defined and validated, as well as the communication between the two energy apps. For this purpose, several tests will be carried out.

Activation phase: The energy generation forecasting together with the energy markets positioning will be run in this phase. The quantification of revenues that the energy markets positioning strategy returned by the algorithm will be done, as well as the actual revenues due to the current operating strategy.

Main phase: This phase will be related to the assessment of the KPIs and how an optimal positioning energy generated at the markets could reduce the risk investment.

The following sequential diagram and flow chart depict how the Demo Case will be implemented:

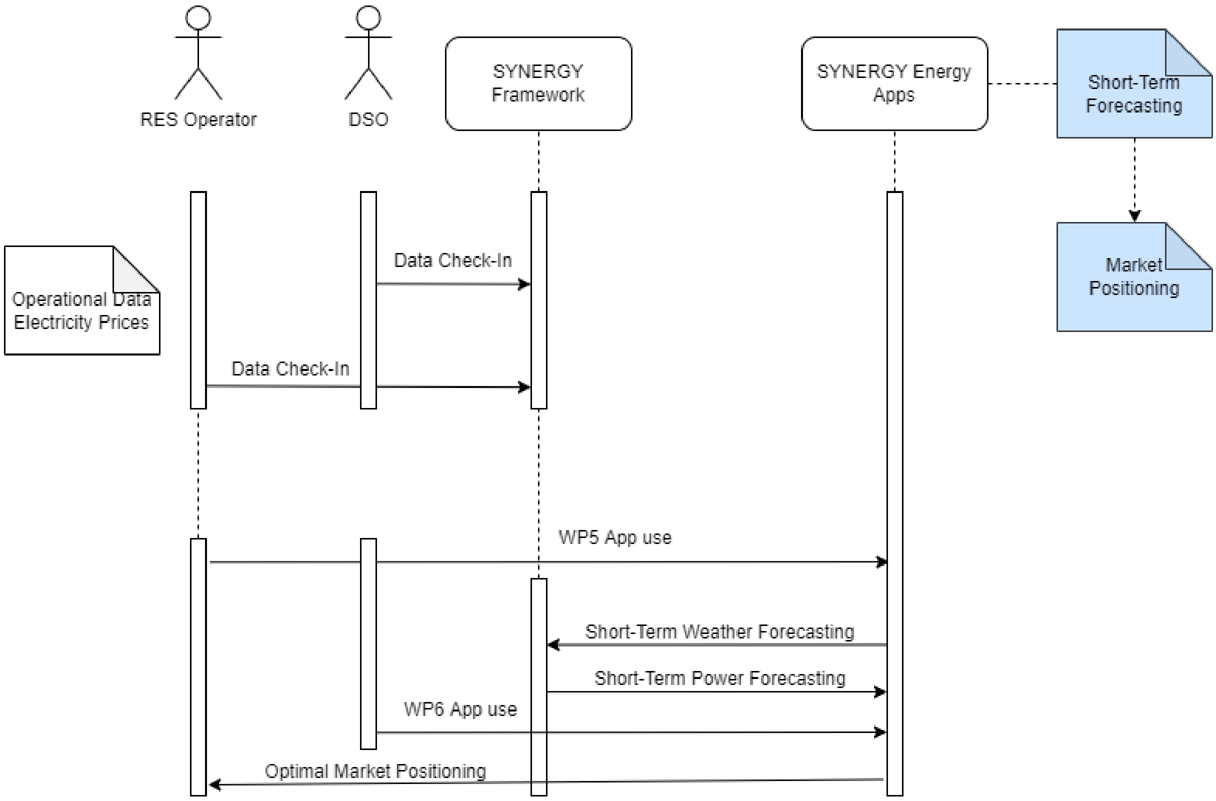

Figure 23: DC8 sequential diagram

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

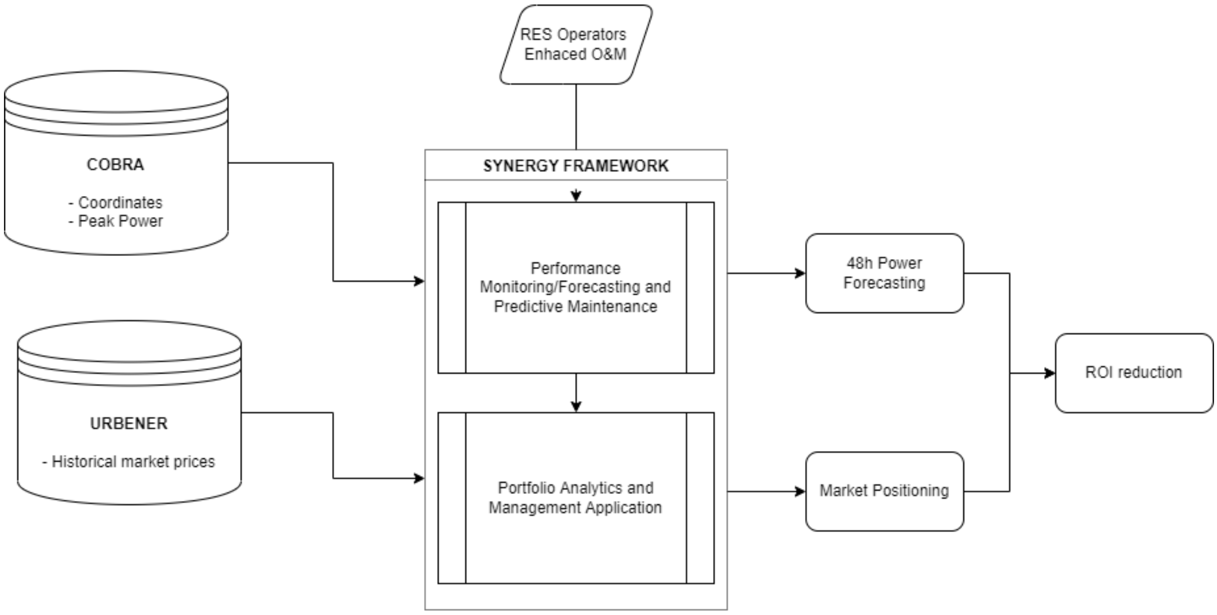

Figure 24: DC8 workflow flowchart

5.2.2.2 Impact KPIs

The main KPIs that will be assessed in demo case 8 are:

- Payback Period (PP): The payback period is the amount of time, typically expressed in years, necessary to recover the cost of an investment, i.e. break-even point is reached.
- Return of Investment (ROI): It is the ratio between net income (over a period) and an investment.

5.2.2.3 Preliminary Evaluation Plan

The evaluation will be centred on the calculation of the two KPIs aforementioned, and the comparison with the values considered during the asset feasibility assessment phase, and with the values of the KPIs estimated after several years of operation. The results will highlight the benefits associated to the innovations and tools developed within the SYNERGY project and the main advantages of using the SYNERGY platform.

Firstly, the information related to the KPIs, considered before implementation of the SYNERGY innovations will be collected. This will require of a continuous communication of the team with the O&M department at the PV plant, as well as with the management team, responsible of the economic indexes analysis and decision making affecting the KPIs considered on a regular basis.

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Secondly, the results after applying the innovations and tools required in this demo case will be calculated. The enhancement on the revenues due to market positioning will be measured and compared to the revenues obtained under normal operation.

Finally, the improvements on the KPIs will be estimated, thus measuring the benefits to which the optimal market positioning tool would lead. This should result in an increase of the revenues related to the energy selling and optimal distribution of the generation in the markets offering the maximum revenues stream, therefore, reducing the risk investment.

This sequence will be followed in both demo runs.

5.2.3 Demo Case 9: Optimising Power Purchase Agreement between RES Operators and Electricity Retailers, towards Greening Electricity Supply and reducing associated tariffs and costs

5.2.3.1 Validation Scenario

Description

This demo case aims to promote the retailing and supply of green electricity and enabling the transition to Sustainable Energy Retailers. A power generation profile will be obtained per power unit at a pre-defined location where the PPA would be evaluated. Then, several user demand scenarios will be generated and crossed with the power production profiles and energy market prices in order to optimise the power for a potential PV plant as well as the PPA price. In the context of the demo case, metering data from different PV plants of COBRA will be fused together with localized weather data in order to enable more accurate generation forecasting. CUERVA will utilize demand profiles from its customers, together with generation and weather data to obtain accurate insights and forecasts about demand and flexibility over its portfolio. Forecasting data from both sides will be injected into an Analytics toolbox that will allow (among others) to effectively match demand and renewable/ green generation and define the amount of energy that should be traded between RES Operators and Retailers for the realization of the 100% green energy supply target. In case of demand forecasting deviations, local dynamic pricing strategies will be applied, incentivising prosumers to reduce their energy consumption and adapt to the renewable generation purchased by Retailers, so as to perform a perfect balancing between green supply and demand. Such dynamic pricing schemes design is further described in the following demo case 10 and will be facilitated by advanced AI flexibility/ elasticity analytics that will be delivered in the frame of the SYNERGY project. Additional benefits are expected for RES Operators since they will be given the opportunity to get involved into long-term energy purchase agreements with retailers, thus reducing related risks (renewable energy not being traded to energy markets) and hedging against market uncertainties. The demo case will assess the feasibility of installing a PV plant at a specific location, whose power will be optimised depending on the optimal PPA price obtained for different demand scenarios.

Objectives

The main targets sought with this demo case are outlined below:

- Objective 1: Foster the green energy supply through the cooperation of RES Operators and Energy Retailers, hence optimising the PPAs between both parties towards a greener energy sector.
- Objective 2: Assessment of the benefits associated to energy end-users by reducing their tariffs.

Stakeholders

- Stakeholder 1: **COBRA** will act as PV Asset owner and RES Operator. Its role will be both, to analyse the operational information coming from the PV plant, analyse the input data and assess the KPIs defined in the demo case.
- Stakeholder 2: **CUERVA** will act as Energy Retailer. Its role will be both, to analyse the operational information coming from the PV plant, analyse the input data and assess the KPIs defined in the demo case.

Use cases

The use cases involved in this demo case are:

- Use case 5_9: Optimized energy bidding and output sharing in PPAs.

Available Data Assets

The data assets that will be used to develop DC 9 are introduced in the following table.

Table 43: Available assets for DC9

Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform
DC9_DN_1	VPP Assets coordinates	CUERVA	Portfolio Analytics and Management Application	Available on 1st iteration

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DC9_DN_2	Demand profiles	CUERVA	Portfolio Analytics and Management Application	Available on 1st iteration
DC9_DN_3	Weather characterisation	COBRA	Performance Monitoring/Forecasting and Predictive Maintenance	Available on 1st iteration
DC9_DN_4	Electricity Market prices	CUERVA	Portfolio Analytics and Management Application	Available on 1st iteration

Energy applications

The energy applications that will be used to develop DC9 are introduced in the next table.

Table 44: Energy applications to be used within DC9

Energy app name	Components	Input data assets (IDA)	Output data assets (ODA)
Performance Monitoring/Forecasting and Predictive Maintenance	A tool that allows PV plant operators to predict the energy generation in the long-term. - Responsible Partner: COBRA	IDA 1: DC9_DN_3 - COBRA	ODA 1: Long-Term unitary power forecasting characterisation - COBRA
Portfolio Analytics and Management Application	A tool that allows the optimisation between RES owners and retailers. PV owners can optimise the power to install and to retailers to optimise the electricity tariff.	IDA2: DC9_DN_1 - CUERVA IDA3: DC9_DN_2 - CUERVA IDA4: DC9_DN_4 - CUERVA	ODA 1: Optimal power size for PV plant and price of the PPA - CUERVA

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	- Responsible Partner: CUERVA		

Data analytics

The analytics that are expected to be used for the implementation of DC9 are introduced in the following table. Data analytics are executed in the SYNERGY Platform

Table 45: Data analytics to be used within DC9

Data Analytics name	Input data assets (IDA)	Output data assets (ODA)
Long-Term Energy Generation Profile	IDA 2: DC9_DN_3 - COBRA	ODA 2: Long-Term unitary power forecasting characterisation - COBRA
Optimal Power of the asset and PPA prices	IDA3: DC9_DN_1 - CUERVA IDA4: DC9_DN_2 - CUERVA IDA5: DC9_DN_4 - CUERVA	ODA 3: Optimal power size for PV plant and price of the PPA - CUERVA

Hardware Components

The demo case does not require of any of any hardware component. It will use input data defined by the user (i.e. peak power of the PV plant) and open source data (i.e. weather forecast, market prices).

Workflow

The workflows to be followed for DC9 will be the same for both demo runs. They consist of three main phases: a preliminary phase in which the procedures and collection of data will be carried out; an activation phase, where the apps to be tested will be implemented at the site; and the main phase, where the app will be running and monitored, in order to assess the benefits of the app.

Preliminary phase: This phase will be focused on the input data collection (e.g. weather data, coordinates, etc.). Two main tasks were identified in this phase:

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- Task 1 Get the historical information from the area:

  1. Inputs for forecasting and generation models (already defined)

  2. Inputs for forecasting economic models:

     - Investment Cost (€/Wp): the scale economic would be considered in the input curve.
     - O&M cost (€/kWh generated): the scale economic would be considered in the input curve.
     - IRR (%) required for investor.
     - Daily market (hourly) price (DMP) forecast (€/MWh).
     - DMP increase: (Tolls, diversion, system costs and marketing margin).
     - Average sales price: DMP + Increase in DMP.

- Task 2 Models Develop definition
  1. Demand forecast

  2. Optimization model

Activation phase: The long-term power forecasting (>10 years) per unit kW, as well as the users' demand profile estimation under different scenarios will be obtained. Then, the Optimal PPA algorithm will be run, outputting the optimal PV power that would be needed to obtain the optimal PPA price. The decision variable to fix the optimal PPA price will be the power of the PV installation. The following variables will be evaluated and obtained from the model:

- Energy Balance. With the energy generation and consumption profiles, an energy balance will be made, and the energy demanded from the power grid and injected into the grid will be known.

- Economic Model. Income and expenses calculations will be done, the price of the PPA will depend on the installed power plant.

- 1000 energy demand scenarios will be obtained. For each of them, the pairs: installed power, PPP price, will be calculated.

- Determination of the optimal size of the PV power plant by solving multiple scenarios:

  - For each Generation-Demand scenario, 20 installed PV power scenarios are analysed (e.g. from 20% to 80% of the maximum historical power demanded)

  - The PPA price is calculated, corresponding to 7% of the IRR.

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- The optimal power is selected, based on the lowest PPA price of the P50 of each PV power analysed.

Main phase: The last phase will be related to the assessment of the savings for the retailer after the construction of the PV power plant, and the energy balance to know which energy from the PV plant is consumed in comparison with initial situation.

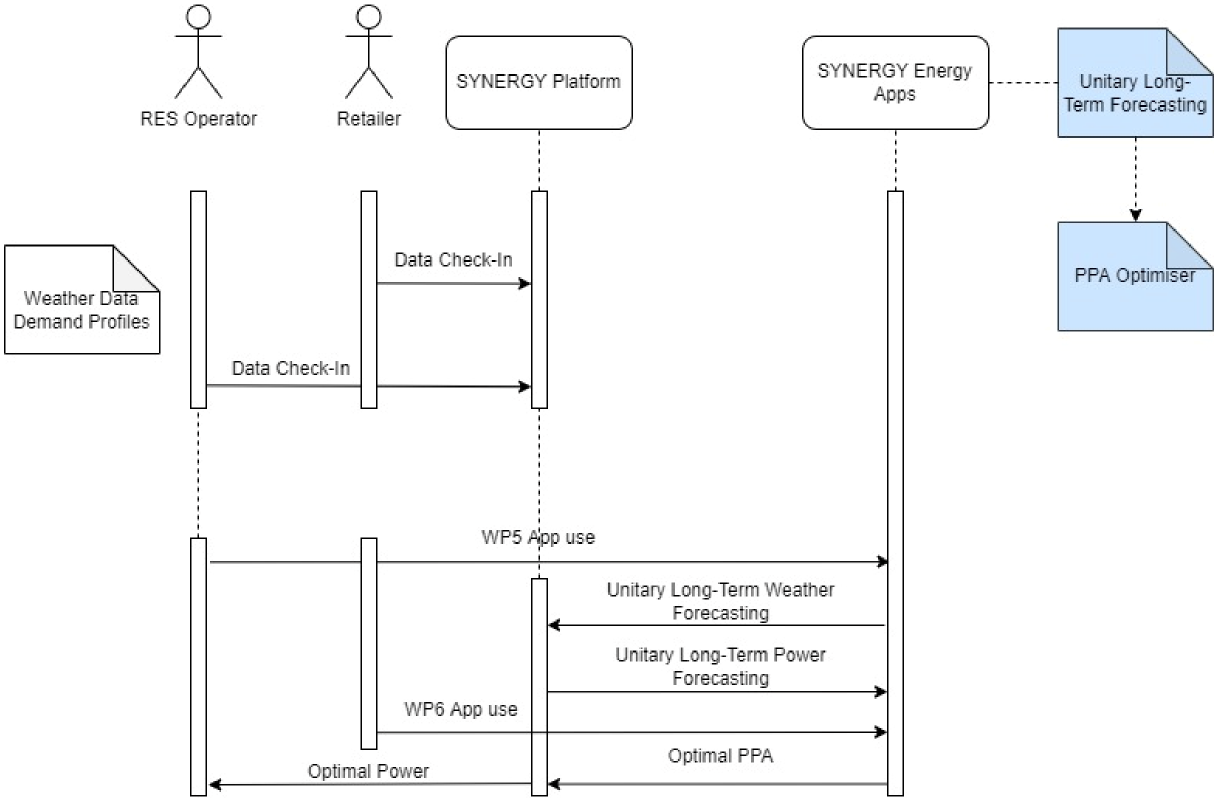

Figure 25: DC9 sequential diagram

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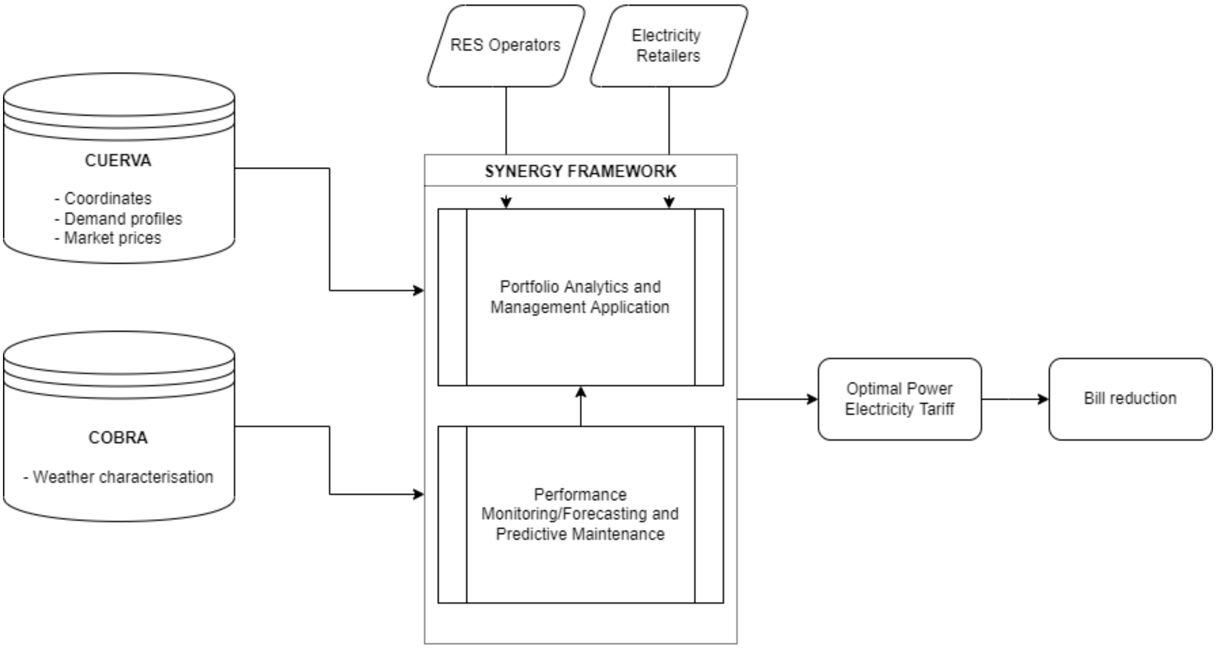

Figure 26: DC9 workflow flowchart

5.2.3.2 Impact KPIs

- Generation forecasting accuracy, essential for establish an optimal PPA between generators and consumers.
- Demand forecasting accuracy, essential for establish an optimal PPA between generators and consumers.

5.2.3.3 Preliminary Evaluation Plan

The evaluation will be centred on the calculation of the two KPIs aforementioned, and the comparison with the values considered during the asset feasibility assessment phase, and with the values of the KPIs estimated after several years of operation. The results will highlight the benefits associated to the innovations and tools developed within the SYNERGY project and the main advantages of using the SYNERGY platform.

Firstly, the information related to the KPIs, considered before implementation of the SYNERGY innovations will be collected.

Secondly, the results after applying the innovations and tools required in this demo case will be calculated. The enhancement on the revenues due to market positioning will be measured and compared to the revenues obtained under normal operation.

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Finally, the improvements on the KPIs will be estimated, thus measuring the benefits to which the optimal market positioning tool would lead. This should result in an increase of the revenues related to the energy selling and optimal distribution of the generation in the markets offering the maximum revenues stream, therefore, reducing the risk investment.

This sequence will be followed in both demo runs.

5.2.4 Demo Case 10: Transformation of the Retailer business model from Commodity to EaaS providers for the implementation of energy efficiency campaigns

5.2.4.1 Validation Scenario

The demo case will be implemented with the involvement of two discrete departments of the same entity (Cuerva acting as both local DSO and retailer) and enable the realization of data synergies between them for the realization of individual optimization goals. Focusing on market roles, the DSO will share with the retailer fine-grained smart metering data and relevant flexibility/ elasticity requirements for optimizing the operation of the local distribution network, in order to avoid congestions and unbalances utilizing features such as generation and demand short term forecasts. Advanced AI analytics will be performed over the available data to enable the retailer to extract the price-based flexibility (elasticity) of their consumer portfolio and enable the effective response to relevant flexibility requirements communicated by the DSO, towards ensuring the resilient and safe operation of the network. Additional value is expected to be generated for the retailer itself which will be equipped with additional analytics and applications for further improving the performance of their portfolio in terms of energy efficiency and, thus, achieving in (i) effectively hedging against imbalances and reducing respective charges through improved demand forecasting and mobilization of dynamic pricing schemes for short-term performance corrections, (ii) optimizing their energy trading/ power exchange functions through improved demand forecasting and avoidance of purchasing additional electricity volumes in highly expensive spot markets, and (iii) complying with Energy Efficiency Obligations imposed at EU and national level, thus avoiding unnecessary penalties. Moreover, retailers will be faced with a unique opportunity that will allow them to move away from the traditional commodity sales business model and adopt a more profitable business orientation that is based on EaaS offering towards their clients, spanning advanced and personalized energy analytics for energy efficiency, intelligent controls and (where possible) smart automation of consumer amenities.

<u>Objectives</u>

The main targets sought with this demo case are outlined below:

- Objective 1: Allow the DSO to solve unbalances and congestions in the grid
- Objective 2: Minimize the penalties associated with an inaccurate forecasting of the Demand & Generation profiles of the customers
- Objective 3: Explore new business models that will allow to offer new Energy as a Service models instead of the traditional ones

Stakeholders

- Stakeholder 1: **CUERVA** will act as DSO and Retailer at the same time. The DSO will share flexibility requirements in its network in order to avoid grid problems (congestion, over or undervoltages, etc.), and the retailer will extract the elasticity of its customer portfolio to enable an effective response to these requirements.

Use cases

The use cases involved in this demo case are:

- Use case 5_1: Simulation-based network performance assessment.
- Use case 6_2: Imbalance risk reduction through explicit demand side management strategies
- Use case 6_3: Retailer portfolio analytics towards the extraction of useful insights.

Available Data Assets

The data assets that will be used to develop DC 10 are introduced in the following table.

Table 46: Available Data Assets for DC10

Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform
DC10_DN_1	Active Power consumption (MWh)	CUERVA	Imbalance risk reduction through explicit demand side management strategies / Retailer portfolio analytics towards the extraction of useful insights.	Available
DC10_DN_2	Voltage (V)	CUERVA	Imbalance risk reduction through explicit demand side management strategies	Available

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DC10_DN_3	Active power (MW)	CUERVA	Imbalance risk reduction through explicit demand side management strategies	Available
DC10_DN_4	Reactive power (MW)	CUERVA	Imbalance risk reduction through explicit demand side management strategies	Available
DC10_DN_5	Grid topology	CUERVA	Imbalance risk reduction through explicit demand side management strategies	Available
DC10_DN_6	GIS - Geographical Information System	CUERVA	Imbalance risk reduction through explicit demand side management strategies	Available
DC10_DN_7	DERs location	CUERVA	Imbalance risk reduction through explicit demand side management strategies / Retailer portfolio analytics towards the extraction of useful insights.	Available

Energy applications

The energy applications that will be used to develop DC10 are introduced in the next table.

Table 47: Energy applications to be used within DC10

Energy app name	Components	Input data assets (IDA)	Output data assets (ODA)
Portfolio Analytics and Management	Customer Segmentation Engine	DC10_DN_1	ODA_1: Elasticity clusters
Infrastructure Sizing and Grid Planning Application	Network Performance Assessment Engine	DC10_DN_2 DC10_DN_3	ODA_2: Detection of congestion problems ODA_3: calculation of flexibility needs

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		DC10_DN_4 DC10_DN_5 DC10_DN_6	

Data analytics

The analytics that are expected to be used for the implementation of DC10 are introduced in the following table. Data analytics are executed in the SYNERGY Platform, with the exception of simulation algorithms that involve power flow calculations and are executed offline. Those cases are mentioned below in the description as 'executed offline'.

Table 48: Data analytics for DC10

Data Analytics name	Input data assets (IDA)	Output data assets (ODA)
Elasticity Clustering - Customer Segmentation Engine	DC10_DN_1	*Elasticity Clusters: ODA 1- CUERVA*
Detect congestion problems Calculate status indicators - Network Performance Assessment Engine. To be executed offline	DC10_DN_2 DC10_DN_3 DC10_DN_4 DC10_DN_5 DC10_DN_6	*Detection of congestion problems: ODA 2 – CUERVA* *Calculation of flexibility needs: ODA 3 – CUERVA*

Hardware Components

None.

Workflow

First demo run:

- Definition: The definition phase will consist of the validation of the input information of the different grid assets to run the short-term power forecasting algorithm and customers segmentation of the SYNERGY platform, and testing that the data inputting is correct.

  Later, the definition from the retailer side, regarding customer segmentation will be analysed in order to check that information provided by the platform and the application is correct.

- Execution: This phase will be related to the carry out of the difference procedures explained in the definition phase, as well as the exhaustive monitoring and tracking of the strategic KPIs and the positioning of the energy at the different markets. The execution will be done among the M27 and M30.
- Evaluation: The last phase will be related to the assessment of the results and compare them with the original situation prior the implantation of the SYNERGY apps, mainly focusing on the evaluation of KPIs mentioned for this demo case.

Second demo run:

- Definition: The definition phase will consist of the re-adjustment of the input information of the different grid assets to run the short-term power forecasting algorithm and customers segmentation of the SYNERGY platform, and testing that the data inputting is correct

  Also, from the retailer side a re-adjustment, regarding customer segmentation will be performed.
- Execution: This phase will be related to the carry out of the difference procedures explained in the definition phase, as well as the exhaustive monitoring and tracking of the strategic KPIs and the positioning of the energy at the different markets. The execution will be done among the M36 and M40.
- Evaluation: The last phase will be related to the assessment of the results and compare them with the original situation prior the implantation of the SYNERGY apps, mainly focusing on the evaluation of the performance of KPIs mentioned for this demo case.

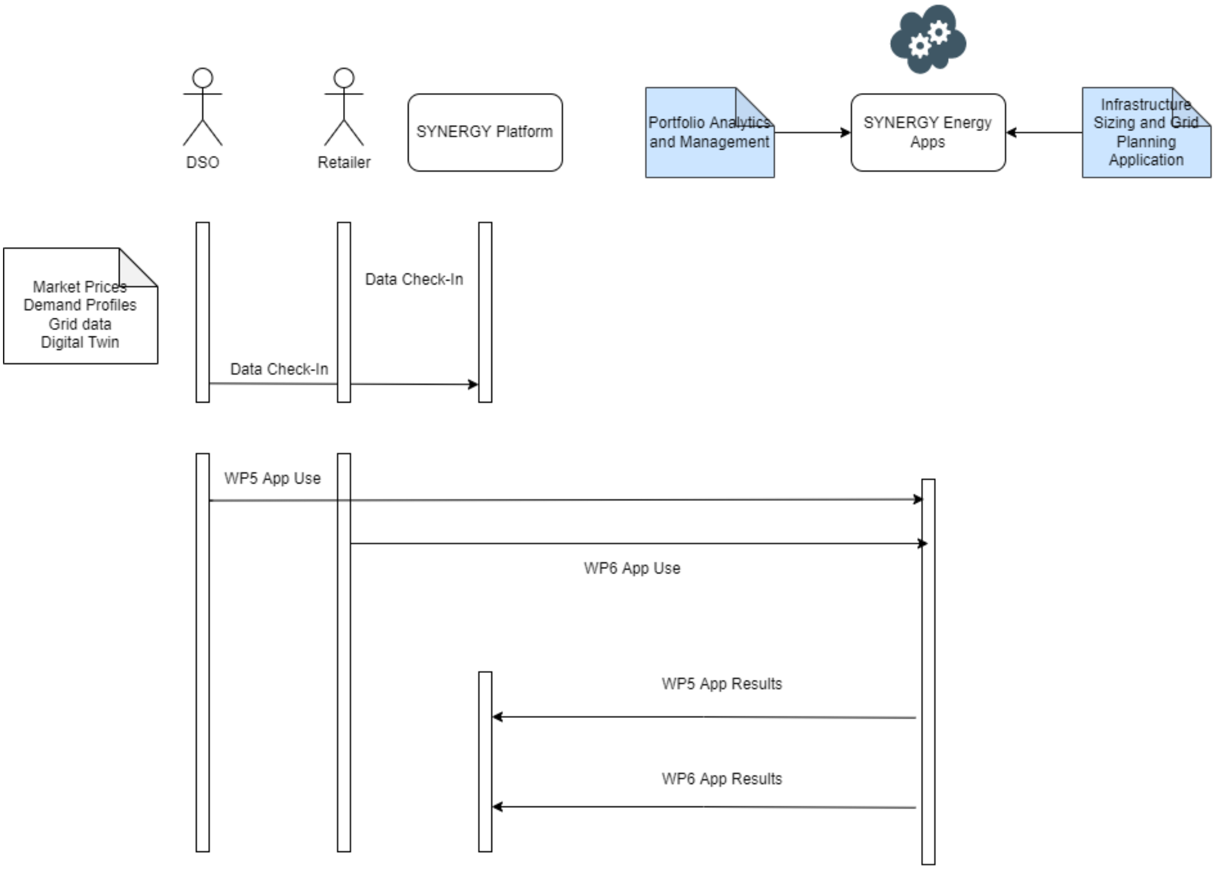

Figure 27: Demo Case 10 sequential diagram

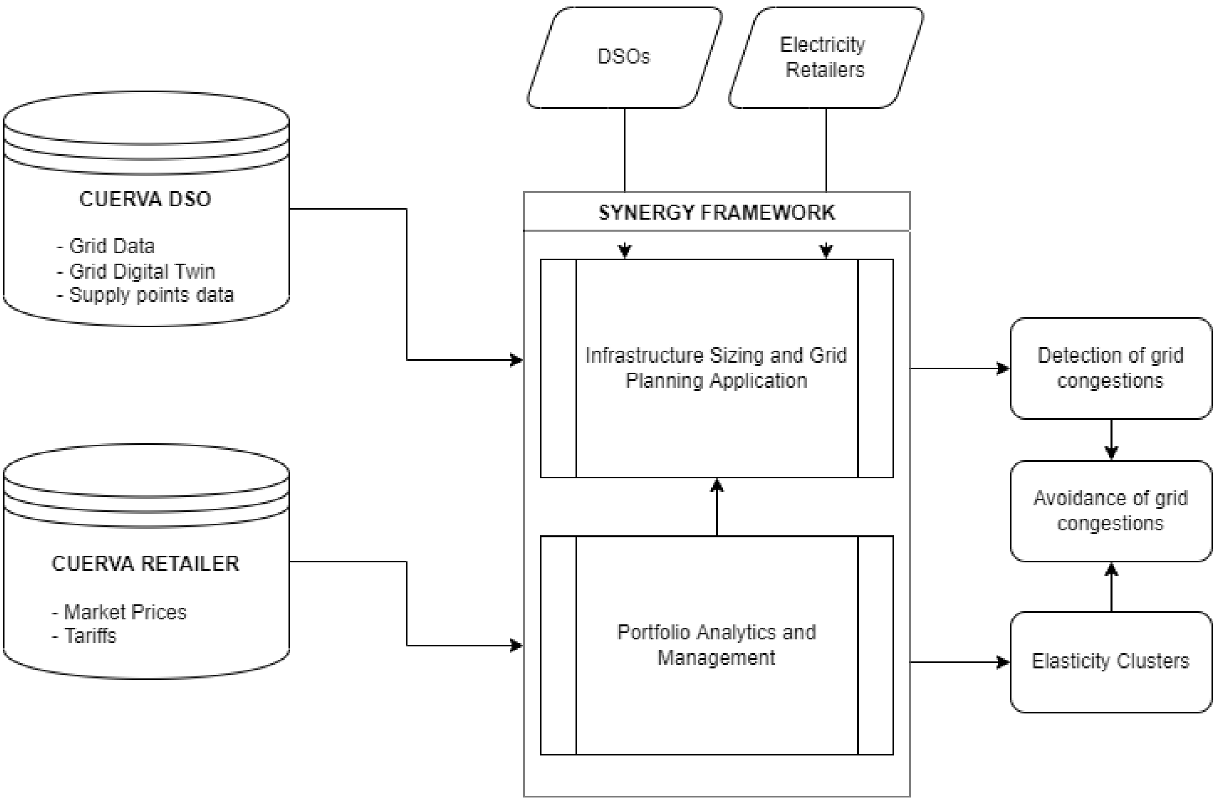

Figure 28: Demo Case 10 workflow flowchart

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5.2.4.2 Impact KPIs

- Congestion alleviation, that calculates the reduction in congestion events in the distribution grid.
- Percentage change of energy consumption for the portfolio

5.2.4.3 Preliminary Evaluation plan

The evaluation will be centred on the evaluation of the two KPIs aforementioned, and the comparison with the values considered during the asset feasibility assessment phase.

The results will highlight the benefits associated to the innovations and tools developed within the SYNERGY project and the main advantages of using the SYNERGY platform.

Firstly, the information related to the KPIs, considered before implementation of the SYNERGY innovations will be collected. This will require of a continuous communication of the team with the DSO grid operation department, as well as with the retailer team, both of them important actors to define the current values of the KPIs.

Secondly, the results after applying the innovations and tools required in this demo case will be calculated. The flexibility provided by the end users will help the grid to reduce the congestions and problems related to high DER penetration in low voltage grids.

Finally, the improvements on the KPIs will be estimated, thus measuring the benefits that a flexibility tool can provide to a DSO.

This sequence will be followed in both demo runs.

5.2.5 Demo Case 11: Enhanced Distribution Network Asset Management and Reinforcement

5.2.5.1 Validation Scenario

Description

The main aim of this demo case is to equip CUERVA with a unique toolbox for Asset Management, towards increasing Network Availability and improving Network Resilience. Network data offered by CUERVA, in-house network data (failures and interruptions, SCADA/DMS information) and data provided by prosumers (smart metering data), will be fused and analysed to provide better visibility into the network assets and proactively predict asset life or anticipated failures, optimize asset investments, prioritize reliability planning and point out common causes of asset failures, thus bringing asset management to an even more advanced level than current practices.

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The Asset Management application that will be delivered by SYNERGY (stepping on appropriate baseline preventive maintenance analytics residing in the SYNERGY analytics marketplace) will analyse historical loading profiles, overloading situations for various assets, and dig through tons of asset operational data to analyse asset loss of life. This will allow operators to right-size the assets, reduce total cost of ownership, and plan for predictive maintenance programs.

Building on condition-based asset analytics, SYNERGY will further allow operators to define risk-based asset management strategies that include failure probabilities, criticality indexing, and device health indexing, thus gaining broader insight into the implications of their asset management decisions, improving maintenance plans as well as perform evidence-based network planning and infrastructure sizing (also considering future penetration of EVs, storage and distributed generation) towards further safeguarding network availability and resilience in the most cost-effective manner (deferral of unnecessary investments).

Objectives

The main targets sought with this demo case are outlined below:

- Objective 1: Accurately provide early alerts by forecasting future events related to Asset Management of Electrical Grids.
- Objective 2: To define and accurately calculate and estimate each asset's health score.
- Objective 3: Support the maintenance operator work in order to improve actuations and reduce time of actuations.
- Objective 4: Analyse all the data regarding the maintenance team (SCADA events, infrared pictures) to improve asset management.

Stakeholders

- Stakeholder 1: **Cuerva will act as DSO.** Its role will be the owner of the grid assets and as maintenance manager.

Use cases

The use cases involved in this demo case are:

- Use case 5_7: Enhanced monitoring of status and health (including VR navigation) of network components
- Use case 5_8: Knowledge-based preventive maintenance scheduling for network assets

Available Data Assets

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The data assets that will be used to develop DC 11 are introduced in the following table.

Table 49: Available Data Assets for DC11

Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform
DC11_DN_1	Active Power consumption (MWh)	CUERVA	Network Asset Health Estimator / Network Predictive Maintenance Manager	Available
DC11_DN_2	Voltage (V)	CUERVA	Network Asset Health Estimator / Network Predictive Maintenance Manager	Available
DC11_DN_3	Active power (MW)	CUERVA	Network Asset Health Estimator / Network Predictive Maintenance Manager	Available
DC11_DN_4	Reactive power (MW)	CUERVA	Network Asset Health Estimator / Network Predictive Maintenance Manager	Available
DC11_DN_5	Grid topology	CUERVA	Network Asset Health Estimator / Network Predictive Maintenance Manager	Available
DC11_DN_6	GIS - Geographical Information System	CUERVA	Network Asset Health Estimator / Network Predictive Maintenance Manager	Available

<u>Energy applications</u>

The energy applications that will be used to develop DC11 are introduced in the next table.

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Table 50: Energy applications for DC11

Energy app name	Components	Input data assets (IDA)	Output data assets (ODA)
Asset Management Optimization Application	Network Predictive Maintenance Manager	DC11_DN_2 DC11_DN_3 DC11_DN_4 DC11_DN_6	ODA_1: Metrics visualization
Asset Management Optimization Application	Network Asset Health Estimator	DC11_DN_2 DC11_DN_3 DC11_DN_4 DC11_DN_6	ODA_1: Asset Health Score Calculation

Data analytics

The analytics that are expected to be used for the implementation of DC11 are introduced in Table 50. Data analytics are executed in the SYNERGY Platform.

Table 51: Available Data Analytics for DC11

Data Analytics name	Input data assets (IDA)	Output data assets (ODA)
Operational and strategic KPI calculations	*DC11_DN_2* *DC11_DN_3* *DC11_DN_4* *DC11_DN_6*	*Metrics Visualization: ODA 1-CUERVA*
Anomaly detection in the performance of grid assets	*DC11_DN_2* *DC11_DN_3* *DC11_DN_4* *DC11_DN_6*	*Asset Health Score Calculation: ODA 2 - CUERVA*

Hardware Components

None.

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Workflow

We have defined two main phases, a first demo run and a second demo run to finally validate this demo case.

Three main tasks have been identified per each demo run:

- First demo run
  - Definition: The definition phase will consist of the validation of the input information of the different grid assets to run both applications: the Network Asset Health Estimator and the Network Predictive Maintenance Manager. Also, information from the maintenance manager will be taken into account.
  - Execution: This phase will be related to the carry out of the difference procedures explained in the definition phase, as well as the exhaustive monitoring and tracking of the strategic KPIs related with maintenance. The execution will be done among the M27 and M30.
  - Evaluation: The last phase will be related to the assessment of the results and compare them with the original situation prior the implantation of the SYNERGY apps, mainly focusing on the evaluation of the performance of both applications.
- Second demo run
  - Definition: The definition phase will consist of the re-adjustment of the input information of the different grid assets to run both maintenance applications on the SYNERGY platform. Also, from the maintenance manager some indications and re-adjustments will be performed.
  - Execution: This phase will be related to the carry out of the difference procedures explained in the definition phase, as well as the exhaustive monitoring and tracking of the strategic KPIs related with maintenance. The execution will be done among the M36 and M40.
  - Evaluation: The last phase will be related to the assessment of the results and compare them with the original situation prior the implantation of the SYNERGY apps, mainly focusing on the evaluation of the performance of both applications.

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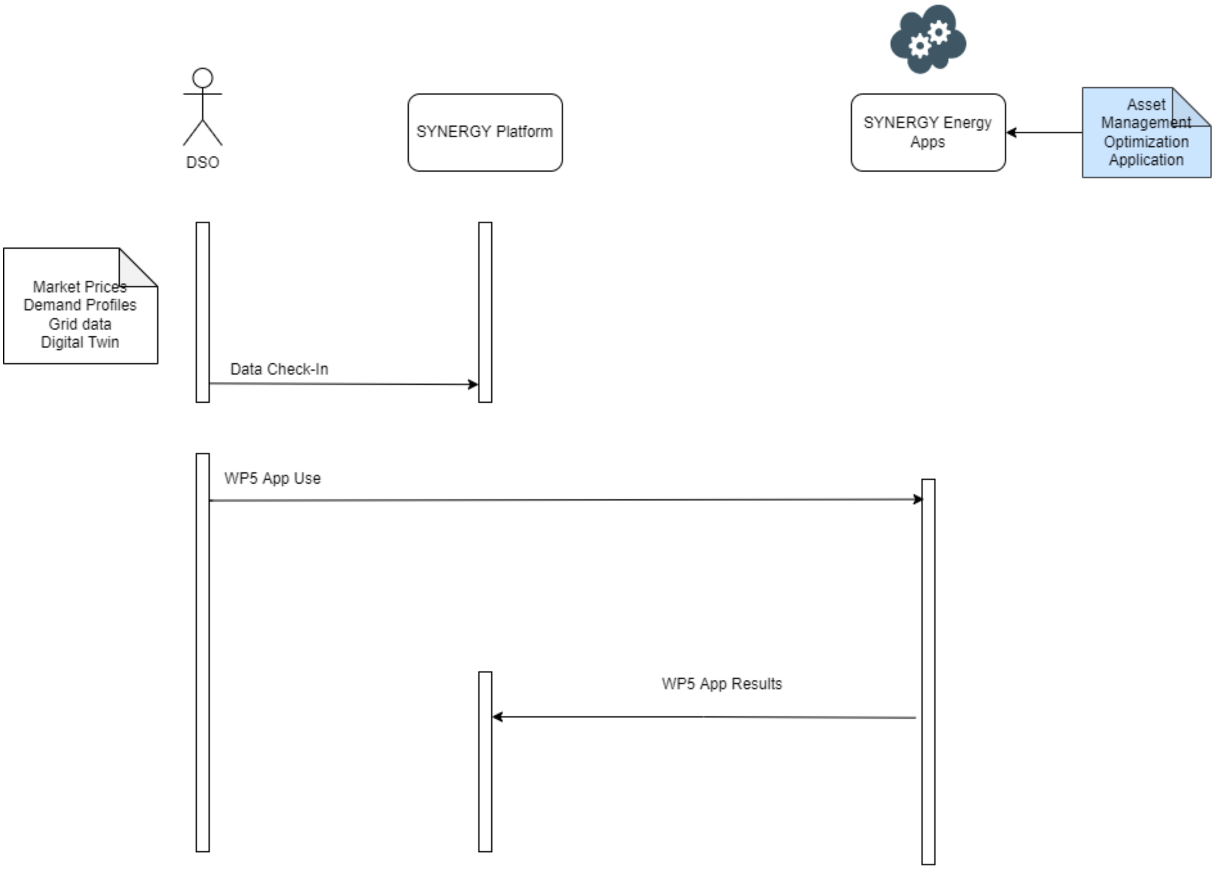

Figure 29: DC 11 sequential diagram

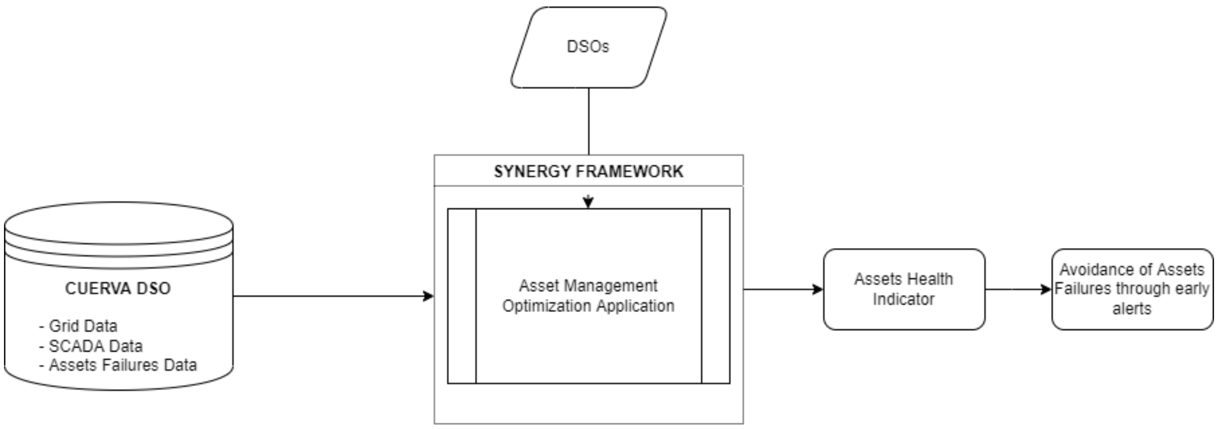

Figure 30: DC11 workflow flowchart

5.2.5.2 Impact KPIs

The main KPIs that will be assessed in demo case 11 are:

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- Asset lifetime extension ratio, after applying predictive maintenance strategies
- Distribution Equipment Maintenance Cost, before and after applying maintenance strategies

5.2.5.3 Preliminary Evaluation plan

The evaluation will be centred on the calculation of the two KPIs aforementioned, and the comparison with the values considered during the asset feasibility assessment phase.

The results will highlight the benefits associated to the innovations and tools developed within the SYNERGY project and the main advantages of using the SYNERGY platform.

Firstly, the information related to the KPIs, considered before implementation of the SYNERGY innovations will be collected. This will require of a continuous communication of the team with the DSO grid operation department, as well as with the maintenance team, both of them important actors to define the current values of the KPIs.

Secondly, the results after applying the innovations and tools required in this demo case will be calculated. The health score of each asset that will be part of the analysis will be calculated to have an estimation of asset's lifespan.

Finally, the improvements on the KPIs will be estimated, thus measuring the benefits that this kind of tool can help a DSO

This sequence will be followed in both demo runs.

5.2.6 Demo Case 12: Innovative Flexibility-based Distribution Network Management

5.2.6.1 Validation Scenario

Description

Smart metering data provided by local prosumers, together with distributed generation data (PV) and SCADA information from the DSO (CUERVA) will be jointly analysed to extract accurate demand and generation forecasts (in the short- and mid-term) and estimate anticipated events in the distribution network and the required flexibility to effectively address them.

Such flexibility requirements will be communicated to the local aggregator (URBENER), together with smart metering, distributed generation and local storage information, allowing for (i) analysis of the flexibility that can be provided by each type of DER at different spatio-temporal granularity, (ii) segmentation and classification of the different types of flexibility according to their characteristics and capability to provide alternative services to the grid operator, (iii) optimal clustering of local

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flexibility sources and formulation of dynamic VPPs to address evolving distribution grid needs and requirements.

Dynamic VPP schedules for flexibility activation will be communicated back to the DSO (CUERVA), allowing for the optimal scheduling of the distribution network operation with these additional flexibility amounts in hand. In turn, the DSO will generate the appropriate signals towards local prosumers and DERs (when required) to enable the provision of the available flexibility with the ultimate target to increase network resilience and operational efficiency, maximize RES integration, minimize power losses, increase power quality and safeguard network availability against anticipated congestions, imbalances, voltage violations, etc.

Objectives

The main targets sought with this demo case are outlined below:

- Objective 1: Accurate forecasting of the grid´s events.
- Objective 2: Accurate calculation of the needed flexibility to solve those grid´s events.
- Objective 3: Accurate forecast of the demand and generation profile of the different supply points.
- Objective 4: Accurately calculate the flexibility that each DER can provide to the grid.

Stakeholders

- Stakeholder 1: **Cuerva will act as DSO.** Its role will be as data asset provider and asset owner, it will be also the technical leader.
- Stakeholder 2: **Urbener** will act as **Aggregator** to optimally set the VPP to solve grid problems.

Use cases

The use cases involved in this demo case are:

- Use case 5_3: Network Flexibility Availability Estimation (short-term).
- Use case 6_5: VPP configuration for the provision of ancillary services to the grid.

Available Data Assets

The data assets that will be used to develop DC 12 are introduced in Table 12

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Table 52: Available Data Assets for DC12

Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform
DC10_DN_1	Active Power consumption (MWh)	CUERVA	Simulation based network performance assessment / Virtual Power Plant (VPP) Configuration Engine	Available
DC10_DN_2	Voltage (V)	CUERVA	Simulation based network performance assessment / Virtual Power Plant (VPP) Configuration Engine	Available
DC10_DN_3	Active power (MW)	CUERVA	Simulation based network performance assessment / Virtual Power Plant (VPP) Configuration Engine	Available
DC10_DN_4	Reactive power (MW)	CUERVA	Simulation based network performance assessment / Virtual Power Plant (VPP) Configuration Engine	Available
DC10_DN_5	Grid topology	CUERVA	Simulation based network performance assessment	Available
DC10_DN_6	GIS - Geographical Information System	CUERVA	Simulation based network performance assessment	Available
DC10_DN_7	DERs location	CUERVA	Simulation based network performance assessment / Virtual Power Plant (VPP) Configuration Engine	Available

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Energy applications

The energy applications that will be used to develop DC12 are introduced in the next table.

Table 53: Energy applications to be used within DC12

Energy app name	Components	Input data assets (IDA)	Output data assets (ODA)
Flexibility based Network Management and DSO-TSO common operational scheduling Application	Flexibility based Network Management	DC10_DN_1 DC10_DN_2 DC10_DN_5 DC10_DN_6 DC10_DN_7	ODA_1: flexibility deficit ODA_2: margins and flexibility requirements
Flexibility Analytics and Consumer – Centric DR Optimization	VPP Configuration Engine	DC10_DN_1 DC10_DN_2 DC10_DN_5 DC10_DN_6 DC10_DN_7	ODA_3: Configuration of the VPP

Data analytics

The analytics that are expected to be used for the implementation of DC12 are introduced in **Error! Reference source not found.**. Data analytics are executed in the SYNERGY Platform, with the exception of simulation algorithms that involve power flow calculations and are executed offline. Those cases are mentioned below in the description as 'executed offline'.

Table 54: Data analytics to be used within DC12

Data Analytics name	Input data assets (IDA)	Output data assets (ODA)
Calculate flexibility deficit periods Identify flexibility products in need (Flexibility based Network Management)	DC10_DN_1 DC10_DN_2 DC10_DN_5 DC10_DN_6	*Elasticity Clusters: ODA 1- CUERVA* *Margins and flexibility requirements: ODA 2 - CUERVA*

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To be executed offline	DC10_DN_7	
Portfolio Flex Optimization (VPP Configuration Engine)	DC10_DN_1 DC10_DN_2 DC10_DN_5 DC10_DN_6 DC10_DN_7	*Configuration of the VPP: ODA 3 – CUERVA*

Hardware Components

None.

Workflow

First demo run:

- Definition: The definition phase will consist on the validation of a first simulation of the grid status with the Flexibility Based Network Management application. Then, the scenario for the network flexibility availability will be defined. Also, the consideration for the VPP set from the Aggregator side will be performed. All will be among the M23 and M27.
- Execution: This phase will be related with the performance of all the simulations. First, the assessment application, then the flexibility availability estimation, and finally the VPP configuration engine. All will be among the M27 and M30.
- Evaluation: The last phase will be related to the assessment of the results and compare them with the original situation prior the implantation of the SYNERGY apps, mainly focusing on the evaluation of flexibility needed to solve grid problems.

Second demo run:

- Definition: The definition phase will consist of the re-adjustment of the input information of the different grid assets to run all the applications.
- Execution: This phase will be related to the carry out of the difference procedures explained in the definition phase, as well as the exhaustive monitoring and tracking of the strategic KPIs. The execution will be done among the M36 and M40.
- Evaluation: The last phase will be related to the assessment of the results and compare them with the original situation prior the implantation of the SYNERGY apps, mainly focusing on the evaluation of the performance of the three applications

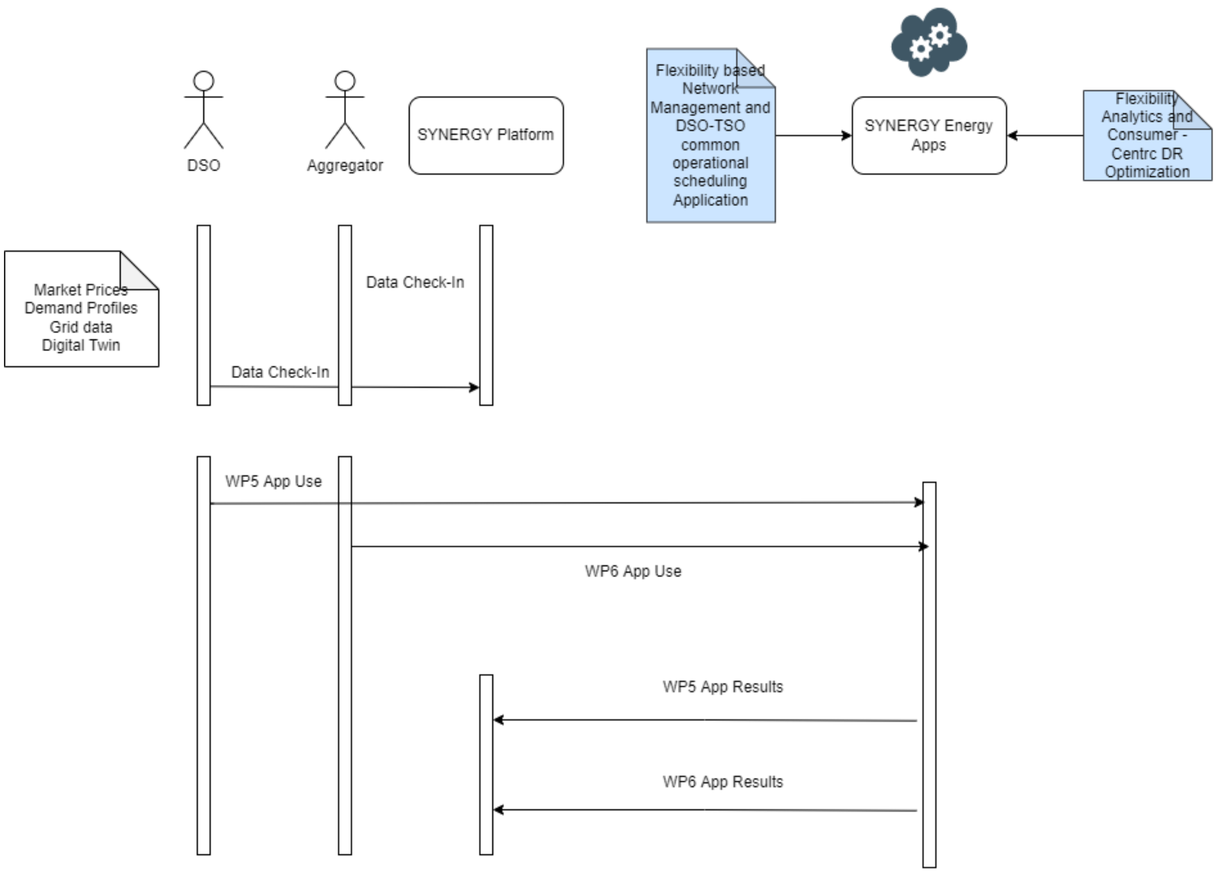

Figure 31:DC12 sequential diagram

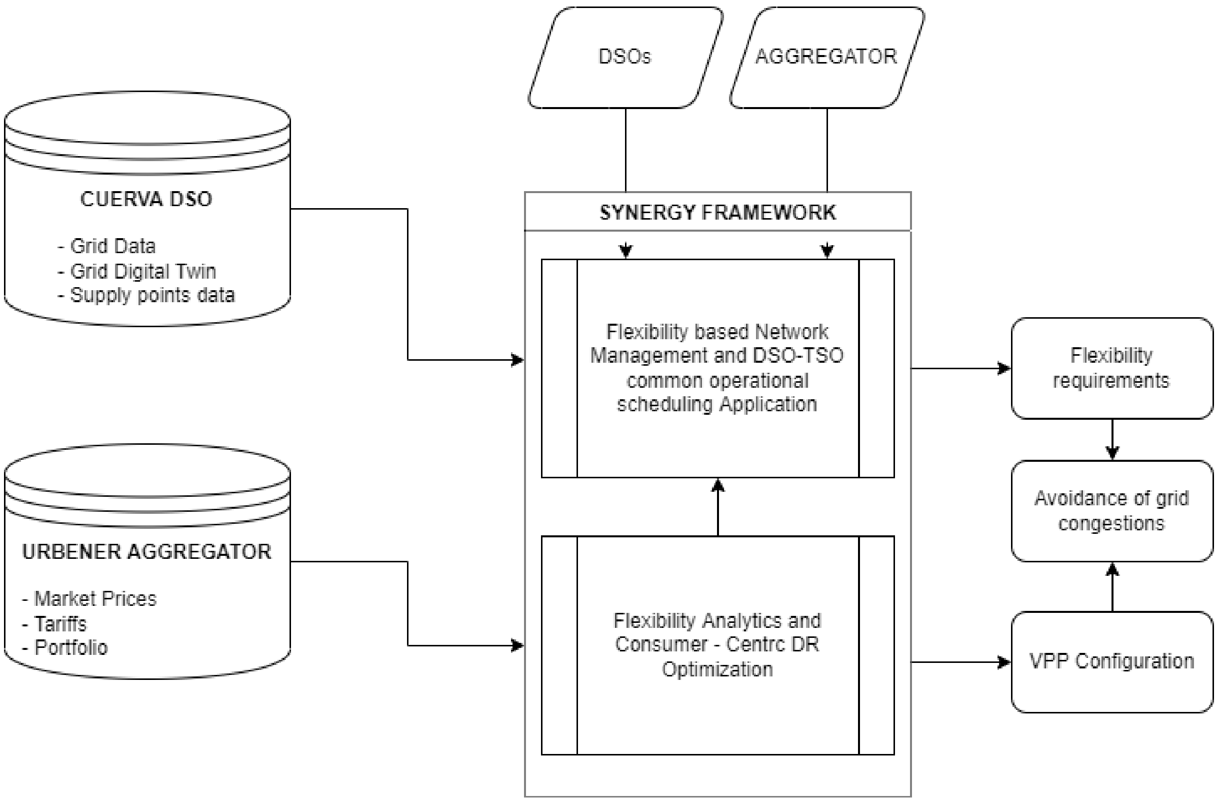

Figure 32: DC12 workflow flowchart

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

5.2.6.2 Impact KPIs

The main KPIs that will be assessed in demo case 12 are:

- Frequency of flexibility request for ancillary services, used for giving services to the distribution grid
- Volume of flexibility requested, for evaluating the total amount of flexibility requested by the network operator.

5.2.6.3 Preliminary Evaluation Plan

The evaluation will be centred on the evaluation of the two KPIs aforementioned, and the comparison with the values considered during the asset feasibility assessment phase.

The results will highlight the benefits associated to the innovations and tools developed within the SYNERGY project and the main advantages of using the SYNERGY platform.

Firstly, the information related to the KPIs, considered before implementation of the SYNERGY innovations will be collected. This will require of a continuous communication of the team with the DSO grid operation department as well as the aggregator, both of them important actors to define the current values of the KPIs.

Secondly, the results after applying the innovations and tools required in this demo case will be calculated. The flexibility provided by the aggregation of the end users through a VPP will help the grid to reduce the congestions and problems related to high DER penetration in low voltage grids.

Finally, the improvements on the KPIs will be estimated, thus measuring the benefits that a flexibility tool can provide to a DSO by using a VPP aggregating the flexibility of the end-users.

This sequence will be followed in both demo runs.

5.3 Evaluation in Austrian Demo

5.3.1 Demo Case 13: Innovative Flexibility-based Network Management

5.3.1.1 Validation Scenario

Description

The increasing penetration of volatile RES, like PV and wind and the transformation of the distribution grid into a smart grid needs a dynamic and steady measurements of the grid and an analysis of the gathered data, ensure a reliability grid operation. In order to address these challenges at different grid levels additional information from prosumer, like smart metering data, prosumer IoT data and DER, renewable energy sources and loads from substations could be included into the analysis of available flexibilities. Hence, this Demo Case focuses in two Pilot areas, which are located in the district of Güssing and supplied by the distribution grid of the provincial DSO Netz Burgenland GmbH, on the data exchange with the external actors and the improvement of the existing mythologies. The results of this analysis serves in order to propose new alternatives in the short-term estimation of the actual flexibility in each feeder of the substations in the area with the network problems (voltage, congestion).

Objectives

The following objectives/targets have been defined for the Demon Case 13 in Deliverable D8.2 already:

- Target 1: Identify flexibility sources, capabilities and characteristics
- Target 2: Development of availability profiles for individual assets
- Target 3: Estimate anticipated events in the distribution grid
- Target 4: Estimation of required flexibilities
- Target 5: Maximize RES integration and minimize power losses

Based on these objectives, the following steps for validation are set up to ensure the successful demonstration:

- Validation step 1: Data upload to SYNERGY platform successfully completed by all demo partners
- Validation step 2: Input data is successfully transferred to the Energy applications
- Validation step 3: Application are executed successfully and generate the desired output.
- Validation step 4: Generated profiles for available flexibility (participants) are compared to the estimated flexibility requirements (grid).

Stakeholders

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

For Demo Case 13, the Austrian Demo partners will undertake the following roles:

- FIB: DSO, Data provider, Data owner, Data Analyst, Data Consumer and Business User
- EEE: Aggregator, Data provider, Data consumer and Business User
- ENES: (Retailer), Data provider, Data Analyst, and Business User

Use Cases

UC_5_1: Simulation-based network performance assessment

UC_5_3:Network flexibility availability estimation (short-term)

Available Data Assets

Since Demo Case 13 represents the first step of the Austrian Demo Analysis and Demonstration all data assets are considered as input for this demo case. Nevertheless, for the actual demonstration, the exact Datapoints within the Data Assets will be defined during the final steps of the demonstration.

Smart metering data, distributed generation data, network data, smart home data from local prosumers, in-house battery storage data, weather data, demand and generation forecasts (short- and mid-term), flexibility requirements, flexibility profiles are some of the data types including below:

Table 55: Available Data Assets for DC13

Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform
AT_FIB_1	Historic measurement Data transformerstation (AT-Pilot Strem)	FIB	Flexibility-Based Network Manager and Network Performance Assessment Engine	available
AT_FIB_2	Actual measurement Data transformerstation (AT-Pilot Strem)	FIB	Flexibility-Based Network Manager and Network Performance Assessment Engine	available

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AT_FIB_3	Historic measurement Data transformerstation (AT-Pilot Güssing-Tobaj)	Netz Burgenland / FIB	Flexibility-Based Network Manager and Simulation based network performance assessment	available
AT_FIB_4	Actual measurement Data transformerstation (AT-Pilot Güssing-Tobaj)	Netz Burgenland / FIB	Flexibility-Based Network Manager and Simulation based network performance assessment	available
AT_FIB_7	Historical Battery Energy Storage System Data	FIB	Flexibility-Based Network Manager and Simulation based network performance assessment	available
AT_FIB_8	Actual Battery Energy Storage System Data	FIB	Flexibility-Based Network Manager and Simulation based network performance assessment	available
AT_EEE_1	Historical PV Data - external	EEE	Flexibility-Based Network Manager and Simulation based network performance assessment	available
AT_EEE_2	Actual PV Data - external	EEE	Flexibility-Based Network Manager and Simulation based network performance assessment	available
AT_EEE_3	Historical IoT - Participant Global Load - data	FIB	Flexibility-Based Network Manager and Simulation based network performance assessment	available
AT_EEE_4	Actual IoT - Participant Global Load - data	FIB	Flexibility-Based Network Manager and Simulation	available

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			based network performance assessment	
AT_ENES_1	Historical Weather Data	ENES	Flexibility-Based Network Manager and Simulation based network performance assessment	available
AT_ENES_2	Actual Weather Data	ENES	Flexibility-Based Network Manager and Simulation based network performance assessment	available

<u>Energy applications</u>

The energy applications that will be used to develop DC13 are introduced in the next table.

Table 56: Energy applications to be used within DC13

Energy app name	Components	Input data assets (IDA)	Output data assets (ODA)
Flexibility based Network Management and DSO-TSO common operational scheduling Application	Flexibility based Network Manager	AT_FIB_1 AT_FIB_2 AT_FIB_3 AT_FIB_4 AT_FIB_7 AT_FIB_8 AT_EEE_1 AT_EEE_2 AT_EEE_3 AT_EEE_4 AT_ENES_1 AT_ENES_2	ODA_1: Flexibility costs ODA_2: Flexibility product requirements ODA_3: calculation of flexibility deficit periods
Infrastructure Sizing and Grid Planning Application	Network Performance Assessment Engine		ODA_4: Generation of sample scenarios ODA_5: power flow calculations ODA_6: congestion detection ODA_7: KPIs engine

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Data analytics

The analytics that are expected to be used for the implementation of DC13 are introduced in the next table. Data analytics are executed in the SYNERGY Platform, with the exception of simulation algorithms that involve power flow calculations and are executed offline. Those cases are mentioned below in the description as 'executed offline'.

Table 57: Data analytics to be used within DC13

Data Analytics name	Description	Input data assets (IDA)	Output data assets (ODA)
Prediction of energy demand at building level in short-term	Learning models for forecasting the total energy demand at different levels (e.g. grid, district portfolio etc.) ICCS, ETRA, UCY, UBI	Time Series and Energy demand data	Energy demand Prediction
Prediction of energy generation in short-term	Learning models for forecasting the total energy generation at different levels (e.g. grid, district portfolio etc.) ICCS, CIRCE, COBRA	Time Series and Energy generation data	Energy generation prediction
Prediction of generation/demand/storag e flexibility at DER level	Analytics for forecasting flexibility generation/demand/storag e at DER level. ICCS, SUITE5	DER level weather and generation/demand/storag e data	Available flexibility at DER level
Aggregate flexibility estimates received from portfolio analytics engine To be executed offline	Aggregate at substation level the flexibility estimates received from the SYNERGY platform ICCS	Time series of flexibility estimation	Aggregation of flexibility in substation and feeder level
Identification of margins/requirements for flexibility	Runs network operational studies to extract network	Network capacity limits and Flexibility resources limitations	Margins to increase/decreas

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	margins and flexibility requirements Executed offline ICCS		e load in each feeder
Calculation of flexibility deficit periods To be executed offline	Identifies deficits on flexibility requirements during the scheduling period Executed offline ICCS	Resulting Flexibility scheduling and Time series of estimated flexibility	Time series of flexibility deficit
Identification of flexibility products in need To be executed offline	Identifies flexibility requirements of network operators and describes them in terms of services Executed offline ICCS	Knowledge of market set up	Corresponding flexibility requirements to available market products
Identification of conflicts in flexibility requirements between operators To be executed offline	Compares flexibility requirements time series from DSO and TSO and identifies conflicts in flexibility needs Executed offline ICCS	Flexibility requests	List of conflicts between requests
Short term DSO scheduling To be executed offline	Performs optimal scheduling algorithms for DSO to decide scheduling for the next hours Executed offline ICCS	Forecasts for short-term demand and DER/RES generation	Upward and downward flexibility scheduling Power deviation Short-term scheduling

<u>Hardware Components</u>

The hardware components that will be used to develop DC13 are introduced in the next table.

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Table 58: Hardware components to be used within DC13

Hardware component id	Application	Input data assets (IDA)	Output data assets (ODA)
HW 1	Smart Home Equipment – FIB	-	IoT Data Prosumer REST (Json)
HW 2	BESS – FIB	-	BEES data REST-API (Json)
HW 3	Raw Data Server – FIB	Energy Demand Metering Prosumer IoT Data Prosumer	IoT – Participant Global Load Transformer Station (Tobaj) REST-API (Json)
HW 4	Energy Data Management – EENS	Transformer station (Tobaj)	Transformer Station (Strem & Tobaj) PV data Weather data REST-API (Json)

<u>Workflow</u>

The following sequential diagram and flow chart describe how the Demo Case will be implemented:

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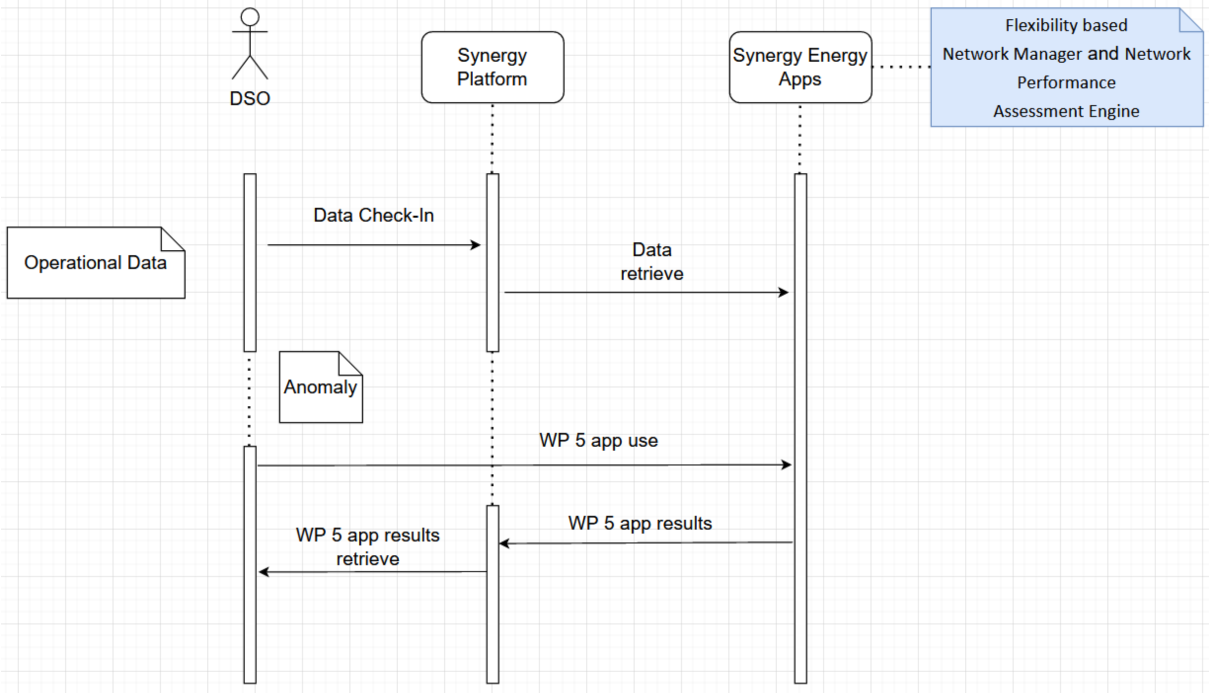

Figure 33: DC 13 sequential diagram

First demo run:

Validation Scenario 1: Data upload to SYNERGY platform

The operational data is collected and pre-processed by the providing partner. Data is uploaded from the different sources; a mapping was performed successfully and was accepted/processed by the Data Ingestion Services of the SYNERGY platform. The data assets are checked to verify that they have been uploaded correctly.

Validation Scenario 2: Input data successfully transferred to the Energy applications

All processed data is available at the synergy platform. The Flexibility based Network Manager and the Network Performance Assessment Engine are invoked, through SYNERGY Platform. Check wheather Flexibility-Based Network Manager and Network Performance Assessment Engine can find and load the correct data assets when they are invoked.

First and second demo run:

Validation Scenario 3: **Application are executed successfully**

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The different data sets available on the SYNERGY platform are successfully processed and executed by the applications. The application outcome is retrieved by the Synergy platform.

Validation Scenario 4: Generated profiles for available flexibility (participants) are compared to the estimated flexibility requirements (grid)

The application is able to process and generate an outcome in different test scenarios, that cover different possible flexibility scenarios.

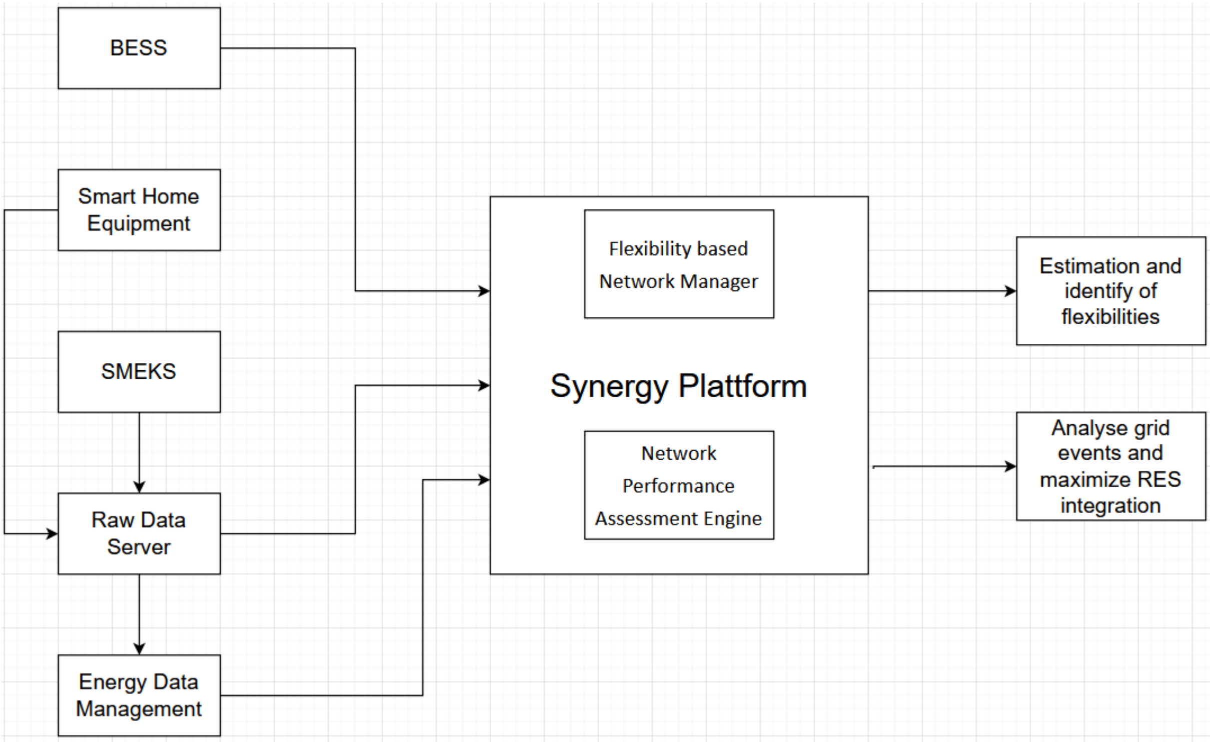

Figure 34: DC13 work flow chart

5.3.1.2 Impact KPIs

The main KPIs that will be assessed in demo case 13 are:

KPI ID	KPI name	KPI impact category	KPI aspect
KPI_1	Peak load demand reduction	Energy	Network observability, Network Availability, Power quality (voltage quality, continuity of supply)
KPI_2	Frequency of congestions	Energy	Network Quality, Network Availability
KPI_3	Size of congestions	Energy	Network Quality, Network Availability

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KPI ID	KPI name	KPI impact category	KPI aspect
KPI_4	Volume of flexibility requested	Energy	Flexibility, DER activation
KPI_5	Congestion alleviation	Energy	Network Quality, Network Availability
KPI_6	Reduction in VRES curtailment	Energy	Energy, RES integration
KPI_7	DER hosting capacity increase	Energy	Energy, RES integration
KPI_8	Active power deviation from flexible units	Energy	Flexibility, DER activation
KPI_9	Activated flexibility compared to available flexibility	Energy	Flexibility, DER activation
KPI_10	Frequency of flexibility requests for ancillary services	Energy	Flexibility, DER activation
KPI_18	Generation forecasting accuracy	Energy	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency, Generation/Demand forecasting
KPI_19	Flexibility Forecasting Accuracy	Energy	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency, Generation/Demand forecasting
KPI_20	Demand forecasting accuracy	Energy	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency, Generation/Demand forecasting
KPI_30	Energy Savings (storage driven/ RES driven)	Energy	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency
KPI_34	Flexibility for the grid and storage for the building	Energy	Energy Efficiency, Retailer Portfolio efficiency, Energy Performance
KPI_41	Time saving to select the required renovation actions	Economic	Urban Planning, Local Energy Communities efficiency
KPI_43	Flexibility on offer	Energy	Flexibility, DER activation
KPI_44	Flexibility on capacity	Energy	Flexibility, DER activation
KPI_45	Actual Flexibility Availability	Energy	Flexibility, DER activation
KPI_46	Flexibility Request	Energy	Flexibility, DER activation
KPI_47	Flexibility Activation	Energy	Flexibility, DER activation
KPI_48	Flexibility Override	Energy	Flexibility, DER activation

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5.3.1.3 Preliminary evaluation plan

The evaluation will be centered on the evaluation of the before mentioned KPI and the comparison with the values considered during the asset feasibility assessment phase. The results will highlight the benefits associated to the innovations and tools developed within the SYNERGY project and the main advantages of using the SYNERGY platform.

In a first demo run the data related to the KPIs considered in the Synergy apps will be collected from different sources and uploaded via data check-in into the Synergy platform. Furthermore, the data needed and uploaded to the SYNERGY platform must be adequately provided and validated in order to ensure that the necessary requirements for the execution of the demo case are met. After these pre-conditions are met, during the second demo run, the developed applications Flexibility-based Network Manager and Network Performance Assessment Engine will be evaluated as a whole, in order to ensure that all of SYNERGY's goals are met successfully.

The results of this analysis serve for designing and developing effective strategies for the distribution network management and provide first outputs utilised for the demonstration of the other Austrian Demo Cases. For this demo case, the presence of demand and available flexibility and the ensuing pairing will be evaluated, so that the delivered outcome is feasible.

5.3.2 Demo Case 14: Local Energy System Optimization and Enhancement of Security of Supply through Islanding

5.3.2.1 Validation Scenario

Description

This Demo Case will validate an innovative concept for local energy system optimization through isolation of specific parts of the distribution grid and their operation in island mode. Hence, in two pilot areas, which are located in the district of Güssing and supplied by the distribution grid of the provincial DSO Netz Burgenland GmbH, data is gathered on grid and prosumer level by the utilization of equipment, which provides IoT connectivity, services for communication, powerful data storage systems. In presence flexible energy providers and by the help of storage system an analysis which address the investigated issues is targeted to identify periods, where parts of the grid could be isolated from the public grid and perform an independent island mode.

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The results of this analysis will facilitate the operational transition of specific parts of the local distribution grid into islanding operation by utilizing the available flexibility resources of the specific area and providing appropriate schedules.

Objectives

The following objectives/targets have been defined for the Demon Case 14 in Deliverable D8.2 already:

- Target 1: Identify flexibility sources, capabilities and characteristics
- Target 2: Development of availability profiles for individual assets
- Target 3: Estimate anticipated events in the distribution grid
- Target 4: Estimation of required flexibilities
- Target 5: Maximize RES integration and minimize power losses

Based on these objectives, the following steps for validation are set up to ensure the successful demonstration:

- Validation step 1: Data upload to SYNERGY platform successfully completed by all demo partners
- Validation step 2: Input data is successfully transferred to the Energy applications
- Validation step 3: Application are executed successfully and generate the desired output.
- Validation step 4: Generated profiles for available flexibility (participants) are compared to the estimated flexibility requirements (grid) lead to conclusions for a possible islanding.

Stakeholders

For Demo Case 14, the Austrian Demo partners will undertake the following roles:

- FIB: DSO, Data provider, Data owner, Data Analyst, Data Consumer and Business User
- EEE: Aggregator, Data provider, Data consumer and Business User
- ENES: (Retailer), Data provider, Data Analyst, and Business User

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Use Cases

UC_5_1: Simulation-based network performance assessment

UC_5_3:Network flexibility availability estimation (short-term)

UC_7_6:Energy performance optimization at district level

Available Data Assets

Smart metering data, distributed generation data, network data, in-house battery storage data, weather data, demand and generation forecasts (short- and mid-term), flexibility requirements, flexibility profiles are example data assets. The data assets that will be used to develop DC 14 are introduced in Table 59.

Table 59: Available Data Assets for DC14

Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform
AT_FIB_1	Historic measurement Data transformerstation (AT-Pilot Strem)	FIB	Flexibility-Based Network Manager, Network Performance Assessment Engine and District-Level Energy Performance Optimisation Manager	available
AT_FIB_2	Actual measurement Data transformerstation (AT-Pilot Strem)	FIB	Flexibility-Based Network Manager, Network Performance Assessment Engine and District-Level Energy Performance Optimisation Manager	available

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

AT_FIB_3	Historic measurement Data transformerstation (AT-Pilot Güssing-Tobaj)	Netz Burgenland / FIB	Flexibility-Based Network Manager, Simulation based network performance assessment and District-Level Energy Performance Optimisation Manager	available
AT_FIB_4	Actual measurement Data transformerstation (AT-Pilot Güssing-Tobaj)	Netz Burgenland / FIB	Flexibility-Based Network Manager, Simulation based network performance assessment and District-Level Energy Performance Optimisation Manager	available
AT_FIB_7	Historical Battery Energy Storage System Data	FIB	Flexibility-Based Network Manager, Simulation based network performance assessment and District-Level Energy Performance Optimisation Manager	available
AT_FIB_8	Actual Battery Energy Storage System Data	FIB	Flexibility-Based Network Manager, Simulation based network performance assessment and District-Level Energy	available

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			Performance Optimisation Manager	
AT_EEE_1	Historical PV Data - external	EEE	Flexibility-Based Network Manager, Simulation based network performance assessment and District-Level Energy Performance Optimisation Manager	available
AT_EEE_2	Actual PV Data - external	EEE	Flexibility-Based Network Manager, Simulation based network performance assessment and District-Level Energy Performance Optimisation Manager	available
AT_EEE_3	Historical IoT - Participant Global Load - data	FIB	Flexibility-Based Network Manager, Simulation based network performance assessment and District-Level Energy Performance Optimisation Manager	available
AT_EEE_4	Actual IoT - Participant Global Load - data	FIB	Flexibility-Based Network Manager, Simulation based network performance assessment and	available

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			District-Level Energy Performance Optimisation Manager	
AT_EEE_5	Historical - IoT - Participant Spaces - data	FIB	District-Level Energy Performance Optimisation Manager (DL-EPOM)	available
AT_EEE_6	Actual - IoT - Participant Spaces - data	FIB	District-Level Energy Performance Optimisation Manager (DL-EPOM)	available
AT_EEE_7	Wallbox EV_Charging_Station	EEE	District-Level Energy Performance Optimisation Manager (DL-EPOM)	-
AT_ENES_1	Historical Weather Data	ENES	Flexibility-Based Network Manager, Simulation based network performance assessment and District-Level Energy Performance Optimisation Manager	available
AT_ENES_2	Actual Weather Data	ENES	Flexibility-Based Network Manager, Simulation based network performance assessment and District-Level Energy	available

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			Performance Optimisation Manager	

Energy applications

The energy applications that will be used to develop DC14 are introduced in the next table.

Table 60 : Energy applications to be used within DC14

Energy app name	Components	Input data assets (IDA)	Output data assets (ODA)
Flexibility based Network Management and DSO-TSO common operational scheduling Application	Flexibility based Network Manager	AT_FIB_1 AT_FIB_2 AT_FIB_3 AT_FIB_4 AT_FIB_7 AT_FIB_8 AT_EEE_1 AT_EEE_2 AT_EEE_3 AT_EEE_4 AT_EEE_5 AT_EEE_6 AT_EEE_7 AT_ENES_1 AT_ENES_2	ODA_1: Aggregation of flexibility in substation and feeder level ODA_2: feeder/substation margins to increase/decrease load ODA_3: calculation of flexibility deficit periods
Infrastructure Sizing and Grid Planning Application	Network Performance Assessment Engine		ODA_4: Generation of sample scenarios ODA_5: power flow calculations ODA_6: congestion detection
Self-Consumption Optimization and Predictive	District-Level Energy Performance Optimisation Manager (DL-EPOM)		ODA_7: solar PV and wind generation during next 72 hours ODA_8: energy prices during next 72 hours ODA_9: weather (external temperatures and humidity

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Maintenance Engine			forecasts, solar irradiance) during next 72 hours ODA_10: building occupation during next 72 hours

Data analytics

The analytics that are expected to be used for the implementation of DC14 are introduced in the next table. Data analytics are executed in the SYNERGY Platform, with the exception of simulation algorithms that involve power flow calculations and are executed offline. Those cases are mentioned below in the description as 'executed offline'.

Table 61: Data analytics to be used within DC14

Data Analytics name	Description	Input data assets (IDA)	Output data assets (ODA)
Prediction of energy demand at building level in short-term	Learning models for forecasting the total energy demand at different levels (e.g. grid, district portfolio etc.) ICCS, ETRA, UCY, UBI	Time Series and Energy demand data	Energy demand Prediction
Prediction of energy generation in short-term	Learning models for forecasting the total energy generation at different levels (e.g. grid, district portfolio etc.) ICCS, CIRCE, COBRA	Time Series and Energy generation data	Energy generation prediction

Prediction of generation/demand/storage flexibility at DER level	Analytics for forecasting flexibility generation/demand/storage at DER level. ICCS, SUITE5	DER level weather and generation/demand/storage data	Available flexibility at DER level
Aggregate flexibility estimates received from portfolio analytics engine (To be executed offline)	Aggregate at substation level the flexibility estimates received from the SYNERGY platform ICCS	Time series of flexibility estimation	Aggregation of flexibility in substation and feeder level
Identification of margins/requirements for flexibility (To be executed offline)	Runs network operational studies to extract network margins and flexibility requirements ICCS	Network capacity limits and Flexibility resources limitations	Margins to increase/decrease load in each feeder
Calculation of flexibility deficit periods (To be executed offline)	Identifies deficits on flexibility requirements during the scheduling period ICCS	Resulting Flexibility scheduling and Time series of estimated flexibility	Time series of flexibility deficit
Identification of flexibility products in need (To be executed offline)	Identifies flexibility requirements of network operators and describes them in terms of services ICCS	Knowledge of market set up	Corresponding flexibility requirements to available market products

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Identification of conflicts in flexibility requirements between operators (To be executed offline)	Compares flexibility requirements time series from DSO and TSO and identifies conflicts in flexibility needs ICCS	Flexibility requests	List of conflicts between requests
Short term DSO scheduling	Performs optimal scheduling algorithms for DSO to decide scheduling for the next hours ICCS	Forecasts for short-term demand and DER/RES generation	Upward and downward flexibility scheduling Power deviation Short-term scheduling

Hardware Components

The hardware components that will be used to develop DC14 are introduced in the next table.

Table 62: Hardware components to be used within DC14

Hardware component id	Application	Input data assets (IDA)	Output data assets (ODA)
HW 1	Smart Home Equipment – FIB Flexibility based Network Manager and Network Performance Assessment Engine	-	IoT Data Prosumer REST (Json)
HW 2	BESS – FIB	-	BEES data

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	Flexibility based Network Manager and Network Performance Assessment Engine		REST-API (Json)
HW 3	Raw Data Server – FIB Flexibility based Network Manager and Network Performance Assessment Engine	Energy Demand Metering Prosumer IoT Data Prosumer	IoT – Participant Global Load Transformer Station (Tobaj) REST-API (Json)
HW 4	Energy Data Management – EENS Flexibility based Network Manager and Network Performance Assessment Engine	Transformer station (Tobaj)	Transformer Station (Strem & Tobaj) PV data Weather data REST-API (Json)

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

Workflow

The following sequential diagram and flow chart describe how the Demo Case will be implemented:

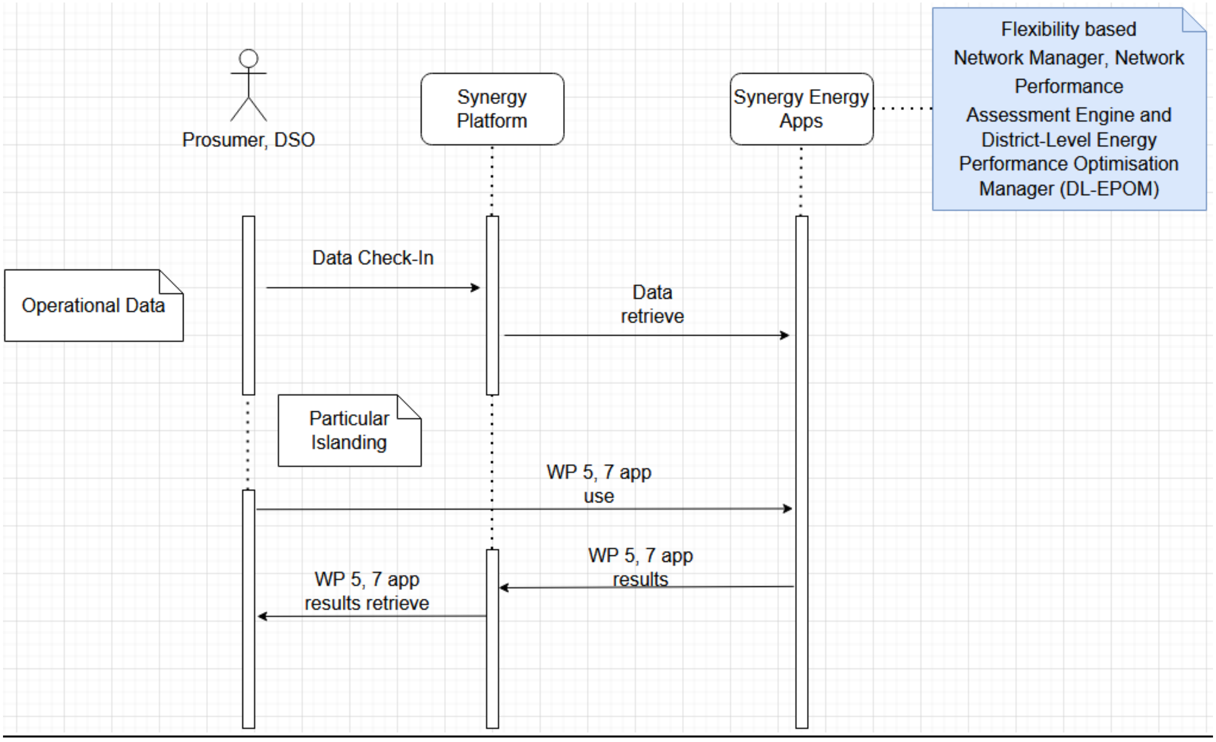

Figure 35: DC 14 sequential diagram

First demo run:

Validation Scenario 1: Data upload to SYNERGY platform

The operational data is collected and pre-processed by the providing partner. Data is uploaded from the different sources; a mapping was performed successfully and was accepted/processed by the Data Ingestion Services of the SYNERGY platform. The data assets are checked to verify that they have been uploaded correctly.

Validation Scenario 2: Input data successfully transferred to the Energy applications

All processed data is available at the synergy platform. The Flexibility based Network Manager and the Network Performance Assessment Engine are invoked, through SYNERGY Platform. Check whether Flexibility-Based Network Manager, Network Performance Assessment Engine and District-Level Energy Performance Optimisation Manager (DL-EPOM) can find and load the correct data assets when they are invoked.

First and second demo run:

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Validation Scenario 3: Application are executed successfully

The different data sets available on the SYNERGY platform are successfully processed and executed by the applications. The application outcome is retrieved by the Synergy platform.

Validation Scenario 4: Generated profiles for available flexibility (participants) are compared to the estimated flexibility requirements (grid) lead to conclusions for a possible islanding.

The application is able to process and generate an outcome in different test scenarios, that cover different possible flexibility scenarios which provide information about a particular gird islanding operation.

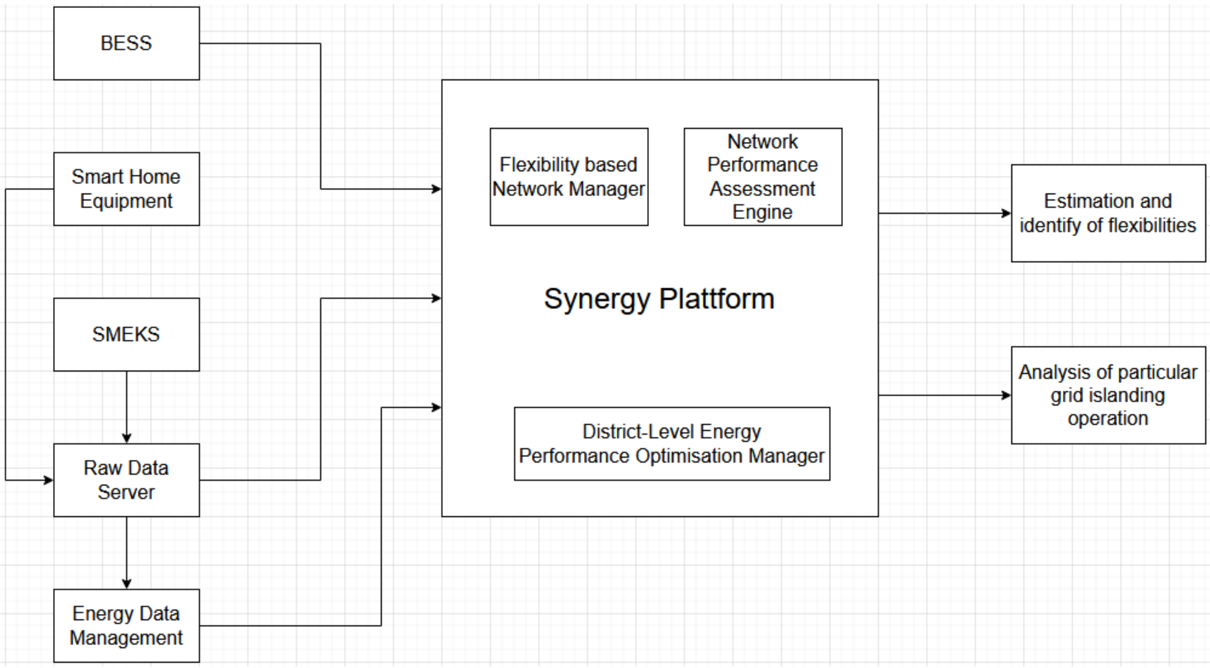

Figure 36: DC14 workflow chart

5.3.2.2 Impact KPIs

The main KPIs that will be assessed in demo case 14 are:

KPI ID	KPI name	KPI impact category	KPI aspect
KPI_1	Peak load demand reduction	Energy	Network observability, Network Availability, Power quality (voltage quality, continuity of supply)
KPI_2	Frequency of congestions	Energy	Network Quality, Network Availability
KPI_3	Size of congestions	Energy	Network Quality, Network Availability

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KPI ID	KPI name	KPI impact category	KPI aspect
KPI_4	Volume of flexibility requested	Energy	Flexibility, DER activation
KPI_5	Congestion alleviation	Energy	Network Quality, Network Availability
KPI_6	Reduction in VRES curtailment	Energy	Energy, RES integration
KPI_7	DER hosting capacity increase	Energy	Energy, RES integration
KPI_8	Active power deviation from flexible units	Energy	Flexibility, DER activation
KPI_9	Activated flexibility compared to available flexibility	Energy	Flexibility, DER activation
KPI_10	Frequency of flexibility requests for ancillary services	Energy	Flexibility, DER activation
KPI_11	Cost of R&I solution VS grid alternative solution	Economic	Cost Savings, O&M Costs savings
KPI_14	Distribution Equipment Maintenance Cost	Economic	Cost Savings, O&M Costs savings
KPI_15	Customers Experiencing Multiple Interruptions	Energy	Network Availability, Network Quality
KPI_16	Asset lifetime extension ratio	Energy	Network Availability, Network Quality
KPI_17	Percentage change of energy consumption for the consumer(a) and the portfolio (b)	Energy	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency
KPI_18	Generation forecasting accuracy	Energy	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency, Generation/Demand forecasting
KPI_19	Flexibility Forecasting Accuracy	Energy	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency, Generation/Demand forecasting
KPI_20	Demand forecasting accuracy	Energy	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency, Generation/Demand forecasting
KPI_21	The gap between predicted and actual heating/cooling energy consumption of buildings	Energy	Generation/Demand forecasting
KPI_25	Self-consumption ratio (for the consumer/aggregator)	Energy	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency
KPI_30	Energy Savings (storage driven/ RES driven)	Energy	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency

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KPI ID	KPI name	KPI impact category	KPI aspect
KPI_32	Building's total renewable generation	Energy	RES Integration, Energy Savings, Energy Performance
KPI_33	Energy savings on site for the building	Energy	Energy Savings, Energy Efficiency, Energy Performance
KPI_34	Flexibility for the grid and storage for the building	Energy	Energy Efficiency, Retailer Portfolio efficiency, Energy Performance
KPI_43	Flexibility on offer	Energy	Flexibility, DER activation
KPI_44	Flexibility on capacity	Energy	Flexibility, DER activation
KPI_45	Actual Flexibility Availability	Energy	Flexibility, DER activation
KPI_46	Flexibility Request	Energy	Flexibility, DER activation
KPI_47	Flexibility Activation	Energy	Flexibility, DER activation
KPI_48	Flexibility Override	Energy	Flexibility, DER activation

5.3.2.3 Preliminary evaluation plan

The evaluation will be focused on the evaluation of the before mentioned KPI and the comparison with the values considered during the asset feasibility assessment phase. The results will highlight the benefits associated to the innovations and tools developed within the SYNERGY project and the main advantages of using the SYNERGY platform.

In a first demo run the data related to the KPIs considered in the Synergy apps will be collected from different sources and uploaded via data check-in into the Synergy platform. Furthermore, the data needed and uploaded to the SYNERGY platform must be adequately provided and validated to ensure that the necessary requirements for the execution of the demo case are met. After these pre-conditions are met, during the second demo run, the developed applications Flexibility-based Network Manager, Network Performance Assessment Engine and District-Level Energy Performance Optimisation Manager (DL-EPOM) will be evaluated as a whole, in order to ensure that all of SYNERGY’s goals are met successfully.

The results of this analysis serve for designing and developing effective strategies for the distribution network management operating particular feeders in an islanding mode. For that, the presence of

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demand and available flexibility from DC13 leads to an assumption which provides first outputs utilized for the evaluation of islanding certain parts of a distribution grid.

5.3.3 Demo Case 15: Flexibility segmentation, classification and clustering towards VPP configuration for flexibility activation and explicit demand response

5.3.3.1 Validation Scenario

Description

Demo Case 15, similar to Demo Case 5, aims to sequentially establish optimal Virtual Power Plant (VPP) compositions based upon the management of flexibility availabilities (profiles) utilizing the results of Demo Case 13 for flexibility activation and demand response.

The validation of this Demo Case is making use of the Flexibility Analytics and Consumer-Centric Demand Response (DR) Optimization App, created within SYNERGY to determine optimal VPP configurations according to the available flexibility profiles. Furthermore, the Personalized Energy Analytics App as well as the Self Consumption Optimization & Predictive Maintenance App are used and included in the validation scenario of this Demo Case.

The inputs regarding the demonstration scenarios of this Demo Case are the following data assets: smart metering data, generation data, sub-metering data from local prosumers, IoT and sensing data from prosumer premises, in-house local storage data, contractual data, weather data as well as the flexibility requirements gathered as an output of Demo Case 13.

Objectives

The main targets sought with this demo case are outlined below:

- Target 1: Analysis of available data sources including flexibility calculations of DC_13
- Target 2: Segmentation, classification and application of flexibility sources
- Target 3: Establish optimal Virtual Power Plant (VPP) composition
- Target 4: Detailed analysis and optimization at building level and district level

The objectives for the validation scenario are classified as follows:

- Objective 1: Data upload to SYNERGY platform successfully completed by all demo partners
- Objective 2: Utilization of DC13 Output (Flexibility Availabilities) functioning properly

- Objective 3: Data input to the utilized Apps for this Demo case is working successfully
- Objective 4: Determination of optimal VPP clustering is successfully working
- Objective 5: Successful determination of the outputs of the utilized Apps

Stakeholders

For Demo Case 15, the Austrian Demo partners will undertake the following roles:

- FIB: DSO, Data provider, Data owner, Data Analyst, Data Consumer and Business User
- EEE: Aggregator, Data provider, Data consumer and Business User
- ENES: (Retailer), Data provider, Data Analyst, and Business User

Use Cases

UC_6_4: Flexibility segmentation, classification and clustering

UC_6_5:VPP configuration for the provision of ancillary services to the grid

UC_6_6: Intelligent human-centric control

UC_7_5:Energy Performance optimization at building level

UC_7_6: Energy Performance optimization at district level

Available Data Assets

Smart metering and generation data will be utilised together with sub-metering and IoT and sensing data from prosumer premises will be analysed together with weather data and information extracted from the previous demo cases.

Table 63: Available Data Assets for DC15

Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform
AT_FIB_1	Historic measurement Data transformation(AT-Pilot Strem)	FIB	Flexibility Analytics and Consumer-Centric DR Optimization	available

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			Self-Consumption Optimization & Predictive Maintenance App	
AT_FIB_2	Actual measurement Data transformation (AT-Pilot Strem)	FIB	Flexibility Analytics and Consumer-Centric DR Optimization Self-Consumption Optimization & Predictive Maintenance App	available
AT_FIB_3	Historic measurement Data transformation (AT-Pilot Güssing-Tobaj)	Netz Burgenland / FIB	Flexibility Analytics and Consumer-Centric DR Optimization Self-Consumption Optimization & Predictive Maintenance App	available
AT_FIB_4	Actual measurement Data transformation (AT-Pilot Güssing-Tobaj)	Netz Burgenland / FIB	Flexibility Analytics and Consumer-Centric DR Optimization Self-Consumption Optimization & Predictive Maintenance App	available
AT_FIB_7	Historical Battery Energy Storage System Data	FIB	Flexibility Analytics and Consumer-Centric DR Optimization	available

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			Personalized Energy Analytics App Self-Consumption Optimization & Predictive Maintenance App	
AT_FIB_8	Actual Battery Energy Storage System Data	FIB	Flexibility Analytics and Consumer-Centric DR Optimization Personalized Energy Analytics App Self-Consumption Optimization & Predictive Maintenance App	available
AT_EEE_1	Historical PV Data - external	EEE	Flexibility Analytics and Consumer-Centric DR Optimization Personalized Energy Analytics App Self-Consumption Optimization & Predictive Maintenance App	available
AT_EEE_2	Actual PV Data - external	EEE	Flexibility Analytics and Consumer-Centric DR Optimization	available

			Personalized Energy Analytics App Self-Consumption Optimization & Predictive Maintenance App	
AT_EEE_3	Historical IoT - Participant Global Load - data	FIB	Flexibility Analytics and Consumer-Centric DR Optimization Personalized Energy Analytics App Self-Consumption Optimization & Predictive Maintenance App	available
AT_EEE_4	Actual IoT - Participant Global Load - data	FIB	Flexibility Analytics and Consumer-Centric DR Optimization Personalized Energy Analytics App Self-Consumption Optimization & Predictive Maintenance App	available
AT_EEE_5	Historical IoT - Participant Spaces - data	FIB	Flexibility Analytics and Consumer-Centric DR Optimization	available

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			Personalized Energy Analytics App Self-Consumption Optimization & Predictive Maintenance App	
AT_EEE_6	Actual IoT - Participant Spaces - data	FIB	Flexibility Analytics and Consumer-Centric DR Optimization Personalized Energy Analytics App Self-Consumption Optimization & Predictive Maintenance App	available
AT_ENES_1	Historical Weather Data	ENES	Self-Consumption Optimization & Predictive Maintenance App	available
AT_ENES_2	Actual Weather Data	ENES	Self-Consumption Optimization & Predictive Maintenance App	available

<u>Energy applications</u>

The energy applications that will be used to develop DC15 are introduced in the next table.

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Table 64: Energy applications to be used within DC15

Energy app name	Components	Input data assets (IDA)	Output data assets (ODA)
Flexibility Analytics and Consumer-Centric DR Optimization Component: Aggregator Portfolio Manager	The component in charge of facilitating aggregators to have a clear picture and management of their portfolio's performance, in order to be able to deliver the required flexibility to network operators considering the flexibility characteristics of their customer S5	IDA 1 – FIB (AT_FIB_1 to AT_FIB_ 8) IDA 2 – EEE (AT_EEE_1 to AT_EEE_6)	ODA1 –DER Flexibility Profiles ODA2 –Building Level Flexibility Profiles ODA3 –Flexibility Clusters
Flexibility Analytics and Consumer-Centric DR Optimization Component: VPP configuration engine	Provide advanced Decision Support System (DSS) functionalities towards creating ad-hoc dynamic Virtual Power Plants (VPP) considering the type of service requested by the network operator and the flexibility characteristics of its underlying portfolio. The VPP Configuration Engine is able to continuously monitor the performance of the VPP and re-configure on	IDA 1 – FIB (AT_FIB_1 to AT_FIB_ 8) IDA 2 – EEE (AT_EEE_1 to AT_EEE_5)	ODA1 –DER Flexibility Profiles ODA2 –Building Level Flexibility Profiles ODA3 – Portfolio Flexibility Strategies

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	the fly the initial VPP once a flexibility source has unexpectedly withdrawn from the VPP during the evolution of a flexibility provision event. S5		
Personalized Energy Analytics App Component: Personalized Energy Analytics Engine	Personalized Energy Analytics Engine component will be used to study consumption patterns and obtain targeted suggestions for improving energy performance - ETRA	IDA 1 – FIB (AT_FIB_6 to AT_FIB_ 8) IDA 2 – EEE (AT_EEE_1 to AT_EEE_5)	ODA 1 - Historical data per customer ODA 2 - Temporal energy usage clusters ODA 3 - Socioeconomic clusters???
Self-Consumption Optimization & Predictive Maintenance App Component: Building-Level Energy Performance Optimization Manager	This module will address the objectives raised by use case 7.5 and can be summarized as the calculation of the operation profile of manageable systems that maximize self-consumption and reduce energy costs according to the expected building energy demand and generation and its systems state.	IDA 1 – FIB (AT_FIB_6 to AT_FIB_ 8) IDA 2 – EEE (AT_EEE_1 to AT_EEE_5) IDA 3 – ENES (AT_ENES_1 to AT_ENES_2)	ODA1 – Control strategy / operation set-points to maximize self-consumption of buildings
Self-Consumption Optimization	This module will address the objectives raised by use case 7.6 and can be	IDA 1 – FIB (AT_FIB_1 to AT_FIB_ 8)	ODA1 – Control strategy / operation set-points to maximize

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& Predictive Maintenance App Component: District-Level Energy Performance Optimization Manager	summarized as the calculation of the operation profile of manageable systems that maximize self-consumption and reduce energy costs according to the expected district energy demand and generation and its systems state.	IDA 2 – EEE (AT_EEE_1 to AT_EEE_5) IDA 3 – ENES (AT_ENES_1 to AT_ENES_2)	self-consumption of districts (group of uildings)

Data analytics

The analytics that are expected to be used for the implementation of DC15 are introduced in the next table. Data analytics are executed in the SYNERGY Platform.

Table 65: Data analytics to be used within DC15

Data Analytics name	Description	Input data assets (IDA)	Output data assets (ODA)
Flexibility Profile Clustering	Apply ML based clustering techniques to extract portfolio clusters on the basis of flexible asset characteristics S5	DERs Operational Characteristics Flexibility Profiles	Flexibility Clusters
Portfolio Flex Optimization	Develop an optimization algorithm for the optimal placement of flexible assets in 3rd party business requests S5	Flexibility Contract Details 3rd Party Flexibility Request Portfolio Flexibility Clusters DER Flexibility Profiling Building level Flexibility Profiling	Portfolio Flexibility Strategies

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DER Flexibility Profiling	Develop an optimization algorithm for the optimal placement of flexible assets in 3rd party business requests S5	DERs Operational and Energy Parameters	DER Flexibility Profiles
Flexibility Aggregation	Simple aggregations of flexibility over time to support visualization of flexibility potential S5	Flexibility Profiles	Aggregate Flexibility Values
Baseline Energy Profiling	Train a specific model to provide baseline estimations of energy consumption/generation S5	History of DER/Building Metering Data	Baseline Energy Profiles

Hardware Components

The hardware components that will be used to develop DC15 are introduced in the next table.

Table 66: Hardware components to be used within DC15

Hardware component id	Application	Input data assets (IDA)	Output data assets (ODA)
HW 1	Smart Home Equipment – FIB Flexibility based Network Manager and Network Performance Assessment Engine	-	IoT Data Prosumer REST (Json)
HW 2	BESS – FIB Flexibility based Network Manager and Network Performance Assessment Engine	-	BEES data REST-API (Json)

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HW 3	Raw Data Server – FIB Flexibility based Network Manager and Network Performance Assessment Engine	Energy Demand Metering Prosumer IoT Data Prosumer	IoT – Participant Global Load Transformer Station (Tobaj) REST-API (Json)
HW 4	Energy Data Management – EENS Flexibility based Network Manager and Network Performance Assessment Engine	Transformer station (Tobaj)	Transformer Station (Strem & Tobaj) PV data Weather data REST-API (Json)

Workflow

The following sequential diagram and flow chart describe how the Demo Case will be implemented:

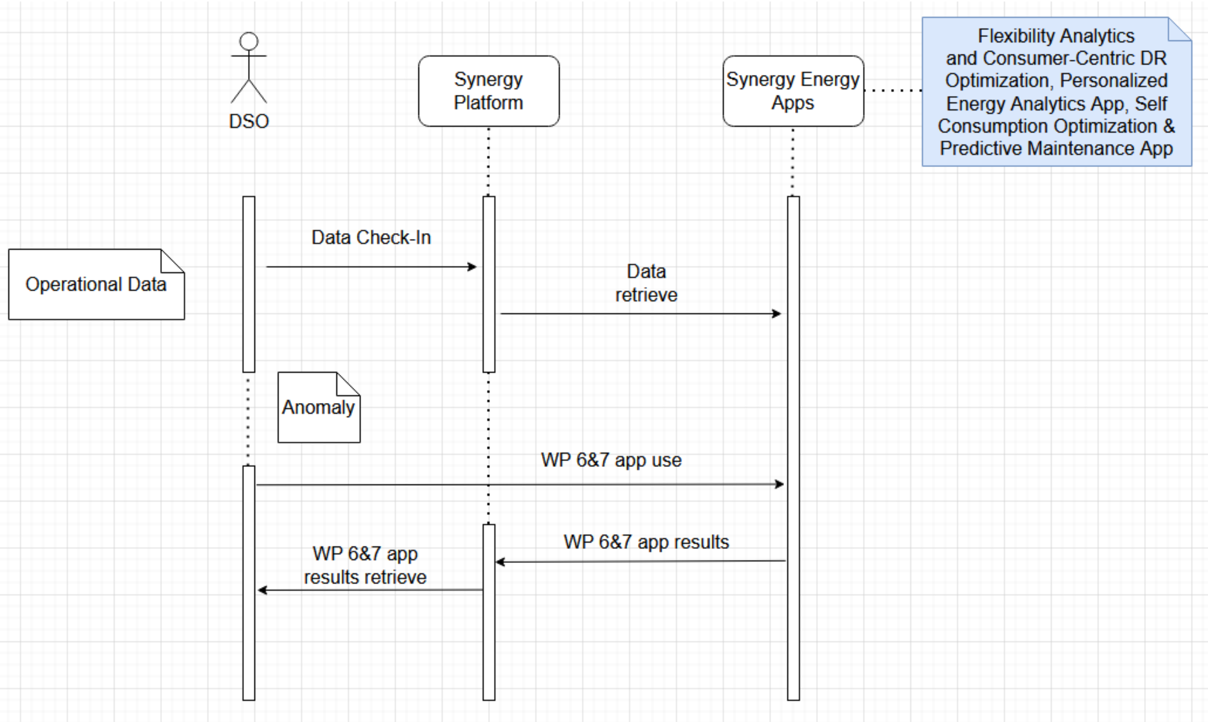

Figure 37: DC 15 sequential diagram

First demo run:

Validation Scenario 1: Data upload to SYNERGY platform

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The operational data is collected and pre-processed by the providing partner. Data is uploaded from the different sources; a mapping was performed successfully and was accepted/processed by the Data Ingestion Services of the SYNERGY platform. The data assets are checked to verify that they have been uploaded correctly.

Validation Scenario 2: Input data successfully transferred to the Energy applications

All processed data is available at the synergy platform. The Flexibility based Network Manager and the Network Performance Assessment Engine are invoked, through SYNERGY Platform. Check whether Flexibility Analytics and Consumer-Centric DR Optimization, Personalized Energy Analytics App, Self Consumption Optimization & Predictive Maintenance App can find and load the correct data assets when they are invoked.

First and second demo run:

Validation Scenario 3: Application are executed successfully

The different data sets available on the SYNERGY platform are successfully processed and executed by the applications. The application outcome is retrieved by the Synergy platform.

Validation Scenario 4: Determination of optimal VPP configurations according to available flexibility profiles

The application is able to sequentially establish optimal Virtual Power Plant (VPP) compositions based upon the management of flexibility availabilities (profiles) utilizing the results of Demo Case 13 for flexibility activation and demand response.

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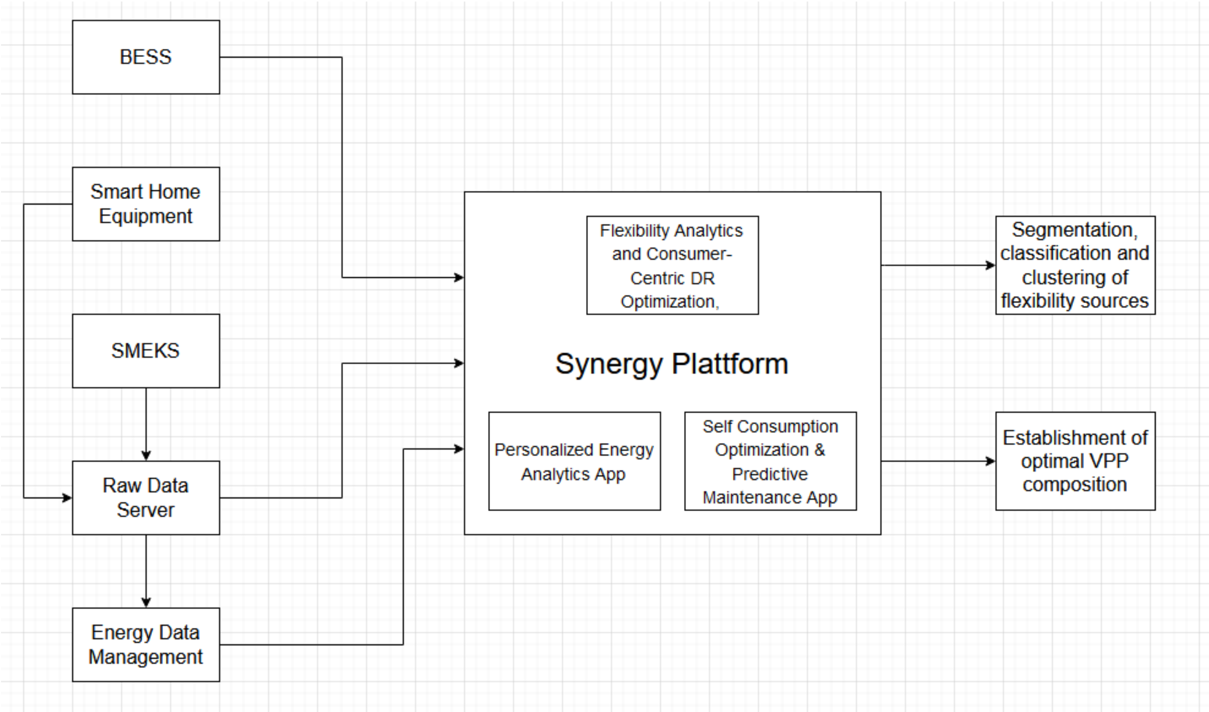

Figure 38: DC 15 workflow chart

5.3.3.2 Impact KPIs

The KPIs that will be assessed in this demo case are:

KPI ID	KPI name	KPI impact category	KPI aspect
KPI_19	Flexibility Forecasting Accuracy	Energy	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency, Generation/Demand forecasting
KPI_20	Demand forecasting accuracy	Energy	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency, Generation/Demand forecasting
KPI_25	Self-consumption ratio (for the consumer/aggregator)	Energy	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency
KPI_30	Energy Savings (storage driven/ RES driven)	Energy	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency
KPI_31	Energy rating of the building	Energy	Energy Performance
KPI_32	Building's total renewable generation	Energy	RES Integration, Energy Savings, Energy Performance
KPI_33	Energy savings on site for the building	Energy	Energy Savings, Energy Efficiency, Energy Performance
KPI_43	Flexibility on offer	Energy	Flexibility, DER activation

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KPI ID	KPI name	KPI impact category	KPI aspect
KPI_44	Flexibility on capacity	Energy	Flexibility, DER activation
KPI_45	Actual Flexibility Availability	Energy	Flexibility, DER activation
KPI_46	Flexibility Request	Energy	Flexibility, DER activation
KPI_47	Flexibility Activation	Energy	Flexibility, DER activation
KPI 48	Flexibility Override	Energy	Flexibility, DER activation

5.3.3.3 Preliminary evaluation plan

The evaluation will be centred on the evaluation of the before mentioned KPI and the comparison with the values considered during the asset feasibility assessment phase. The results will highlight the benefits associated to the innovations and tools developed within the SYNERGY project and the main advantages of using the SYNERGY platform.

In a first demo run the data related to the KPIs considered in the Synergy apps will be collected from different sources and uploaded via data check-in into the Synergy platform. Furthermore, the data needed and uploaded to the SYNERGY platform must be adequately provided and validated in order to ensure that the necessary requirements for the execution of the demo case are met. After these pre-conditions are met, during the second demo run, the developed applications Flexibility Analytics and Consumer-Centric DR Optimization, Personalized Energy Analytics App, Self-Consumption Optimization & Predictive Maintenance App will be evaluated, in order to ensure that all of SYNERGY's goals are met successfully.

The results of this analysis for determining the optimal VPP clustering.

5.3.4 Demo Case 16: Local Flexibility Market for network services and self-consumption through blockchain-enabled smart contract establishment and handling

5.3.4.1 Validation Scenario

Description

Demo Case 16, Flexibility Market for network services and self-consumption through blockchain-enabled smart contract establishment and handling, focuses on the validation of SYNERGY mechanisms and tools allowing local flexibility sources/prosumers to engage in local flexibility market

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transactions. This Demo Case will conclude the demonstration in Austria by connecting the outputs related to the available local flexibility analysis and the local energy market, combining all data sets involved in the analysis of DC 13, 14 and 15, which refer to smart metering, prosumer IoT data, generation and storage data, as well as the results of the executed analysis are gathered with price signals from the energy market to enable the establishment of contracts between the different stakeholders.

On the one side prosumers are able to offer flexibility towards an aggregator or grid operator, while on the other side the flexibility demanding party, i.e. the local DSO, publishes a request for flexibility including the amount, timeframe and price. Once the terms are negotiated a contract between the parties is set up enabling the flexibility utilisation and remuneration process.

With this overall process Demo Case 16 validates the benefits for the involved stakeholders, by providing the direct access to a local flexibility market, where prosumers benefit from reimbursement of the offered and provided flexibility, while at the same time operators benefit from the additional operational possibilities to ensure the continued grid operation.

In order to achieve this Demo Case, all the relevant data need to be communicated through the SYNERGY platform, to the DR Smart Contract Monitoring, Handling, Settlement and Remuneration Platform.

Following validation scenarios can be tested in order to make sure that the outcome is as expected:

- Validation Scenario 1: Data correctly transferred to the SYNERGY platform
- Validation Scenario 2: Data shared between prosumer & aggregator
- Validation Scenario 3: Data received correctly from APP through SYNERGY platform
- Validation Scenario 4: Enabled flexibility transactions with local aggregators

<u>Objectives</u>

Demo case Objectives:

- Target 1: Validation of the SYNERGY mechanisms and tools
- Target 2: Allowing local flexibility sources/ prosumers to engage in local flexibility market transactions
- Target 3: Offering alternative contract types and remuneration methods (both for standby and activated DERs) to prosumers

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- Target 4: Enable prosumers to negotiate & customize their contractual relationship with EEE (in economic terms, also regarding contract duration, number of DER activations, flexibility sharing, etc.)
- Target 5: Enable direct access to the DERs

Objective/goals/targets of the validation scenarios:

- Objective 1: Sharing flexibility data through the SYNERGY platform, enabling prosumers to participate in local flexibility markets
- Objective 2: Empowering of prosumers to benefit from power/flexibility transactions with local aggregators
- Objective 3: Establishment of an advanced Flexibility Settlement and Remuneration process

Stakeholders

Stakeholders involved and their role:

- FIB: Data Provider, Data Owner, Data Analytics, Data Consumer, Business User
- EEE: Data Provider, Data Consumer, Business User, Service Provider
- ENES: Data Provider, Data Analytics, Data Management, Business User, Service Provider

Use Cases

- UC_6_9: Establishment of bilateral flexibility contracts between aggregators and flexibility providers
- UC_6_10: Measurement, verification and real-time settlement of flexibility in local flexibility markets

Available Data Assets

Smart metering and distributed generation data as well as prosumer data including the IoT and metering data is combined with the output data of the previous Demo Cases in regard to available and needed flexibility and will be utilised together with market prices.

Table 67: Available Data Assets for DC16

Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform

AT_FIB_1	Historic measurement Data transformerstation (AT-Pilot Strem)	FIB	Flexibility Analytics and Consumer - Centric DR Optimization and DR Smart Contract Monitoring, Handling, Settlement and Remuneration	available
AT_FIB_2	Actual measurement Data transformerstation (AT-Pilot Strem)	FIB	Flexibility Analytics and Consumer - Centric DR Optimization and DR Smart Contract Monitoring, Handling, Settlement and Remuneration	available
AT_FIB_3	Historic measurement Data transformerstation (AT-Pilot Güssing-Tobaj)	Netz Burgenland / FIB	Flexibility Analytics and Consumer - Centric DR Optimization and DR Smart Contract Monitoring, Handling, Settlement and Remuneration	available
AT_FIB_4	Actual measurement Data transformerstation (AT-Pilot Güssing-Tobaj)	Netz Burgenland / FIB	Flexibility Analytics and Consumer - Centric DR Optimization and DR Smart Contract Monitoring, Handling, Settlement and Remuneration	available
AT_FIB_7	Historical Battery Energy Storage System Data	FIB	Flexibility Analytics and Consumer - Centric DR Optimization and DR Smart Contract Monitoring, Handling, Settlement and Remuneration	available
AT_FIB_8	Actual Battery Energy Storage System Data	FIB	Flexibility Analytics and Consumer - Centric DR Optimization and DR Smart Contract Monitoring, Handling, Settlement and Remuneration	available
AT_EEE_1	Historical PV Data - external	EEE	Flexibility Analytics and Consumer - Centric DR Optimization and DR Smart Contract Monitoring, Handling, Settlement and Remuneration	available

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AT_EEE_2	Actual PV Data - external	EEE	Flexibility Analytics and Consumer - Centric DR Optimization and DR Smart Contract Monitoring, Handling, Settlement and Remuneration	available
AT_EEE_3	Historical IoT - Participant Global Load - data	FIB	Flexibility Analytics and Consumer - Centric DR Optimization and DR Smart Contract Monitoring, Handling, Settlement and Remuneration	available
AT_EEE_4	Actual IoT - Participant Global Load - data	FIB	Flexibility Analytics and Consumer - Centric DR Optimization and DR Smart Contract Monitoring, Handling, Settlement and Remuneration	available
AT_EEE_5	Historical IoT - Participant Spaces - data	FIB	Flexibility Analytics and Consumer - Centric DR Optimization and DR Smart Contract Monitoring, Handling, Settlement and Remuneration	available
AT_EEE_6	Actual IoT - Participant Spaces - data	FIB	Flexibility Analytics and Consumer - Centric DR Optimization and DR Smart Contract Monitoring, Handling, Settlement and Remuneration	available
AT_ENES_1	Historical Weather Data	ENES	Flexibility Analytics and Consumer - Centric DR Optimization and DR Smart Contract Monitoring, Handling, Settlement and Remuneration	available
AT_ENES_2	Actual Weather Data	ENES	Flexibility Analytics and Consumer - Centric DR Optimization and DR Smart Contract Monitoring, Handling, Settlement and Remuneration	available

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AT_ENES_3	Historical Energy Market prices	ENES	Flexibility Analytics and Consumer - Centric DR Optimization and DR Smart Contract Monitoring, Handling, Settlement and Remuneration	available
AT_ENES_4	Actual Energy Market prices	ENES	Flexibility Analytics and Consumer - Centric DR Optimization and DR Smart Contract Monitoring, Handling, Settlement and Remuneration	available

Energy applications

The energy applications that will be used to develop DC16 are introduced in the next table.

Table 68: Energy applications to be used within DC16

Energy app name	Components	Input data assets (IDA)	Output data assets (ODA)
Flexibility Analytics and Consumer-Centric DR Optimization Subcomponent - Aggregator Portfolio Manager	The component in charge of facilitating aggregators to have a clear picture and management of their portfolio's performance, in order to be able to deliver the required flexibility to network operators considering the flexibility characteristics of their customer – S5	AT_FIB_1 AT_FIB_2 AT_FIB_3 AT_FIB_4 AT_FIB_7 AT_FIB_8 AT_EEE_1 AT_EEE_2 AT_EEE_3 AT_EEE_4 AT_ENES_1 AT_ENES_2	ODA 1: Flexibility Profile ODA 2: Flexibility Clusters ODA_1: Flex Clusters Management ODA_2: Flexibility aggregation ODA_3: Flexibility Clusters Visualization ODA 4: Flexibility Filtering
DR Smart Contract Monitoring, Handling, Settlement and Remuneration Platform Subcomponent – Flexibility Marketplace Search Engine	The DR Smart Contract Monitoring, Handling, Settlement and Remuneration Platform implements all necessary features to allow DER Aggregators and Flexible Asset Managers to come into a common marketplace and negotiate the enrolment of the flexibility assets in		ODA 1: Flexibility Profiles ODA_1: Aggregator Marketplace Visualization ODA_2: Asset Manager Marketplace Visualization

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	different flexibility services through a contractual process. The role of the Flexibility Marketplace Search Engine is to facilitate aggregators to search from a pool about flexibility sources with specific characteristics that fit to their business objectives. On the other hand, the flexibility asset managers will have the opportunity to properly configure the characteristics and parameters of their flexible assets in the marketplace, enabling that way their active participation and collaboration in evolving flexibility-based market schemas. S5		ODA_3: Flexibility Aggregation ODA 4: Marketplace Search Configuration
DR Smart Contract Monitoring, Handling, Settlement and Remuneration Platform Subcomponent – Flexibility Contracts Manager	The role of the Flexibility Contracts Manager is to manage the contractual process among aggregators and flexibility asset managers. S5	Customer Configuration Parameters	ODA 1: Information about the contractual agreements among aggregators and flexible asset managers – S5 ODA_1: Aggregator Contracts Management ODA_2: Aggregator Contracts Visualization ODA_3: Asset Manager Contracts Management ODA 4: Asset Manager Contracts Visualization
DR Smart Contract Monitoring, Handling,	The Flexibility Settlement & Remuneration Engine leverages innovative	Information about the contractual agreements among aggregators and	ODA 1 – DER Flexibility Profiles – S5

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Settlement and Remuneration Platform Subcomponent: Flexibility Settlement & Remuneration Engine	energy baseline techniques - further complemented by adjustment and normalization methods –to enable fair settlement and remuneration of the flexibility assets for participation in flexibility services. S5	flexible asset managers – S5 The actual measurement of DER required for the settlement process The flexibility request triggered by the Aggregator to flexibility asset owner for activation of flexibility	ODA 2 – Building level flexibility profiles – S5 ODA 3 – Flexibility Settlement Parameters – S5 ODA 4 – Actual flexibility offer – S5 ODA_1: Aggregator Settlement Visualization ODA_2: Asset Manager Settlement Visualization ODA_3: Flexibility Aggregation ODA 4: Flexibility Remuneration ODA 5: Flexibility Settlement
DR Smart Contract Monitoring, Handling, Settlement and Remuneration Platform Subcomponent – Blockchain wallet	The role of the Blockchain Wallet is to act as the user registry and management layer to enable end user's interaction with the blockchain-enabled smart contract monitoring, handling, settlement and remuneration platform. S5	n/a	n/a

Data analytics

The analytics that are expected to be used for the implementation of DC16 are introduced in the next table. Data analytics are executed in the SYNERGY Platform.

Table 69: Data analytics to be used within DC15

Data Analytics name	Description	Input data assets (IDA)	Output data assets (ODA)

Flexibility Profile Clustering	Apply ML based clustering techniques to extract portfolio clusters on the basis of flexible asset characteristics S5	DERs Operational Characteristics Contract Details Flexibility Profiles	Flexibility Clusters
Flexibility Profiling	Train a specific model to forecast time series of flexibility potential per each smart asset of the building of the portfolio S5	Smart Device Operational and Energy Parameters	Flexibility Profiles
Portfolio Flexibility Optimization	Develop an optimization algorithm for the optimal placement of flexible assets S5	Flexibility Contract Details Flexibility Request Portfolio Flexibility Clusters Flexibility Profiling	Portfolio Flexibility Strategies
Flexibility Aggregation	Simple aggregations of flexibility over time to support visualization of flexibility potential S5	Flexibility Profiles	Aggregate Flexibility Values
Flexibility Settlement	Calculation of flexibility settlement on the basis of flexibility requests and actual energy consumption values	Flexibility Request, Metering Data, Energy Profiles	Flexibility Settlement Parameters, Actual Flexibility Offer
Flexibility Remuneration	Calculation of flexibility remuneration on the basis of flexibility settlement and contractual parameters	Flexibility Settlement, Flexibility Contract Details, DER Flexibility Profile, (Building Level) Demand Flexibility Profile	Flexibility Remuneration Parameters

Hardware Components

The hardware components that will be used to develop DC16 are introduced in the next table.

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Table 70: Hardware components to be used within DC16

Hardware component id	Application	Input data assets (IDA)	Output data assets (ODA)
HW 1	Smart Home Equipment – FIB Flexibility based Network Manager and Network Performance Assessment Engine	-	IoT Data Prosumer REST (Json)
HW 2	BESS – FIB Flexibility based Network Manager and Network Performance Assessment Engine	-	BEES data REST-API (Json)
HW 3	Raw Data Server – FIB Flexibility based Network Manager and Network Performance Assessment Engine	Energy Demand Metering Prosumer IoT Data Prosumer	IoT – Participant Global Load Transformer Station (Tobaj) REST-API (Json)
HW 4	Energy Data Management – EENS Flexibility based Network Manager and Network Performance Assessment Engine	Transformer station (Tobaj)	Transformer Station PV data Weather data REST-API (Json)

<u>Workflow</u>

The following sequential diagram and flow chart describes how the Demo Case will be implemented:

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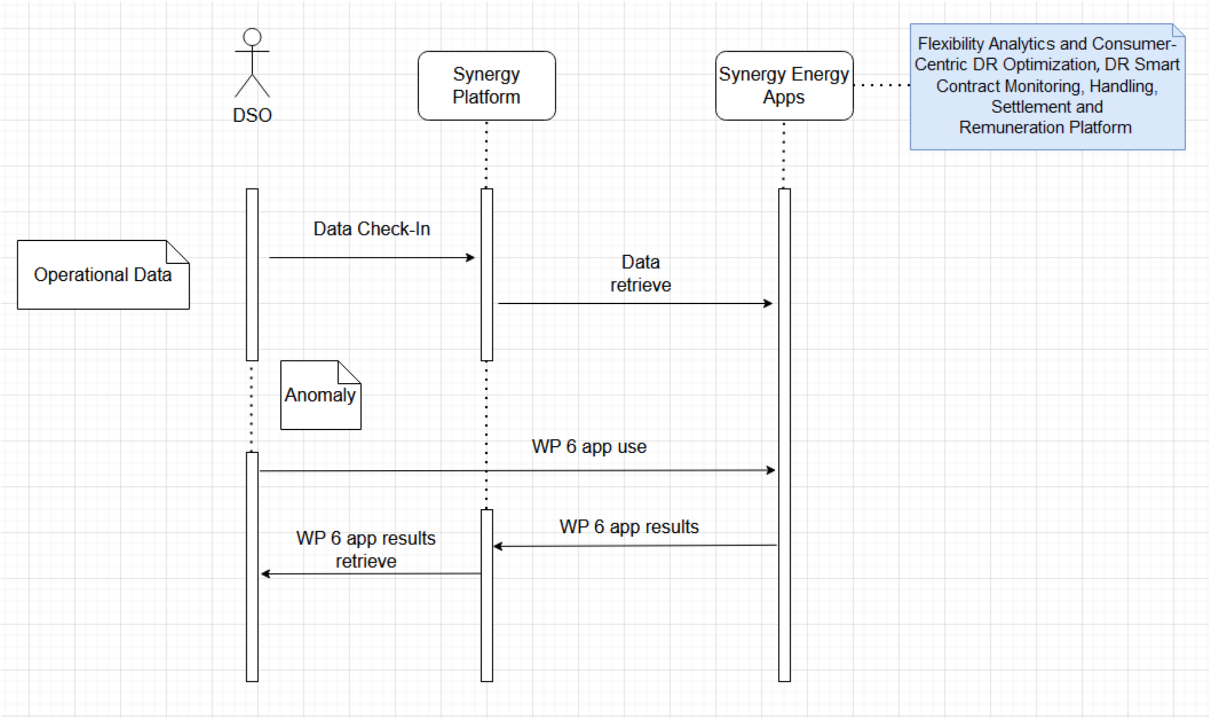

Figure 39: DC 16 sequential diagram

First demo run:

Validation Scenario 1: Data upload to SYNERGY platform

The operational data is collected and pre-processed by the providing partner. Data is uploaded from the different sources; a mapping was performed successfully and was accepted/processed by the Data Ingestion Services of the SYNERGY platform. The data assets are checked to verify that they have been uploaded correctly.

Validation Scenario 2: Input data successfully transferred to the Energy applications

All processed data is available at the synergy platform. The Flexibility based Network Manager and the Network Performance Assessment Engine are invoked, through SYNERGY Platform. Check whether Flexibility Analytics and Consumer-Centric DR Optimization, DR Smart Contract Monitoring, Handling, Settlement and Remuneration Platform can find and load the correct data assets when they are invoked.

First and second demo run:

Validation Scenario 3: Application are executed successfully

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The different data sets available on the SYNERGY platform are successfully processed and executed by the applications. The application outcome is retrieved by the Synergy platform.

Validation Scenario 4: Establishment of smart contracts

All data sets involved in the analysis of DC 13, 14 and 15, which refer to smart metering, prosumer IoT data, generation and storage data, as well as the results of the executed analysis are gathered with price signals from the energy market to enable the establishment of contracts between the different stakeholders.

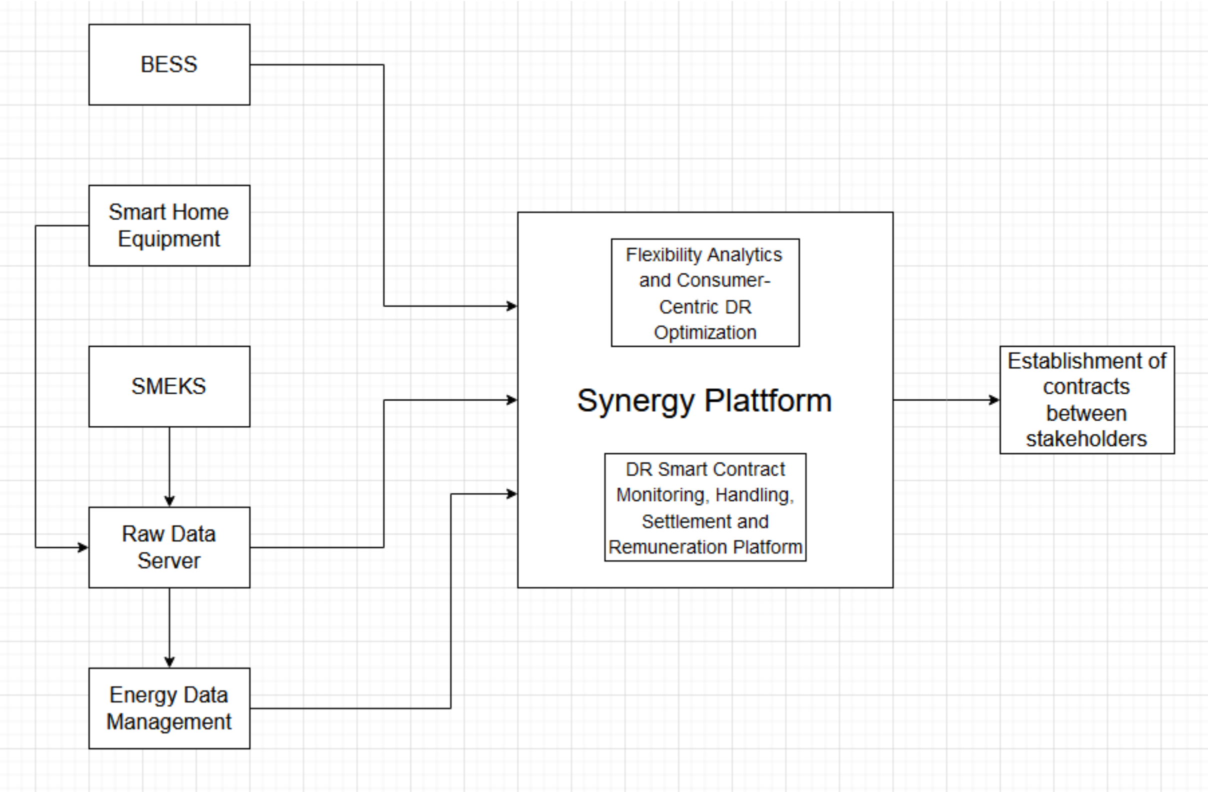

Figure 40: DC 16 workflow chart

5.3.4.2 Impact KPIs

KPI ID	KPI name	KPI impact category	KPI aspect
KPI_4	Volume of flexibility requested	Energy	Flexibility, DER activation
KPI_8	Active power deviation from flexible units	Energy	Flexibility, DER activation
KPI_9	Activated flexibility compared to available flexibility	Energy	Flexibility, DER activation
KPI_10	Frequency of flexibility requests for ancillary services	Energy	Flexibility, DER activation

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KPI ID	KPI name	KPI impact category	KPI aspect
KPI_19	Flexibility Forecasting Accuracy	Energy	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency, Generation/Demand forecasting
KPI_34	Flexibility for the grid and storage for the building	Energy	Energy Efficiency, Retailer Portfolio efficiency, Energy Performance
KPI_43	Flexibility on offer	Energy	Flexibility, DER activation
KPI_44	Flexibility on capacity	Energy	Flexibility, DER activation
KPI_45	Actual Flexibility Availability	Energy	Flexibility, DER activation
KPI_46	Flexibility Request	Energy	Flexibility, DER activation
KPI_47	Flexibility Activation	Energy	Flexibility, DER activation
KPI_48	Flexibility Override	Energy	Flexibility, DER activation
KPI_49	Actual Flexibility on Contract	Energy	Establishment of advanced Flexibility settlement and Remuneration Methods, Alternative (smart) contract types, Smart contract handling mechanisms
KPI_50	Flexibility Request on Contract	Energy	Establishment of advanced Flexibility settlement and Remuneration Methods, Alternative (smart) contract types, Smart contract handling mechanisms
KPI_51	Revenue on Contract	Energy	Establishment of advanced Flexibility settlement and Remuneration Methods, Alternative (smart) contract types, Smart contract handling mechanisms
KPI_52	Penalty on Contract	Energy	Establishment of advanced Flexibility settlement and Remuneration Methods, Alternative (smart) contract types, Smart contract handling mechanisms
KPI_53	Profit on Contract	Energy	Establishment of advanced Flexibility settlement and Remuneration Methods, Alternative (smart) contract types, Smart contract handling mechanisms

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5.3.4.3 Preliminary evaluation plan

The evaluation will be focused on the evaluation of the before mentioned KPI and the comparison with the values considered during the asset feasibility assessment phase. The results will highlight the benefits associated to the innovations and tools developed within the SYNERGY project and the main advantages of using the SYNERGY platform.

In a first demo run the data related to the KPIs considered in the Synergy apps will be collected from different sources and uploaded via data check-in into the Synergy platform. Furthermore, the data needed and uploaded to the SYNERGY platform must be adequately provided and validated in order to ensure that the necessary requirements for the execution of the demo case are met. After these pre-conditions are met, during the second demo run, the developed applications Flexibility Analytics and Consumer-Centric DR Optimization, DR Smart Contract Monitoring, Handling, Settlement and Remuneration Platform will be evaluated, in order to ensure that all of SYNERGY's goals are met successfully.

The results of this analysis serve for validating significant benefits with regards to Prosumer Empowerment, by offering them direct access into local flexibility markets and allowing them to benefit from power/ flexibility transactions with local aggregators, towards ultimately serving high-level operational requirements of overlay distribution networks.

5.4 Evaluation in Finnish Demo

5.4.1 Demo Case 17: Optimized Urban Energy Performance Monitoring and Optimization

5.4.1.1 Validation scenario

Description

The Demo Case 17 uses building energy data from Forum Virium Helsinki (FVH) facilities and external sources to identify anomalies and weaknesses and to design optimal energy management strategies for the realization of short-term objectives and commitments of the city of Helsinki. DC17 does not provide any additional analytical capabilities or use cases, but utilizes the energy datasets and applications to provide an updated situational awareness on the building stock.

The demo case is also related to the Task 6.3 on personalized energy analytics and energy efficiency module, including human-centric automation features. The Urban Energy Monitoring and Planning

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Support App (T7.2) and the elements of Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance Toolbox (T7.3) will be validated here as well.

Objectives

The main targets sought with this demo case are outlined below:

- To demonstrate the ability to collect large data streams (smart metering data) from public and commercial buildings.
- To showcase the data-driven analytics to facilitate the analysis of energy performance along whole districts in the city of Helsinki.
- To demonstrate the ability to identify the weak points in the energy performance of buildings and/or districts in order to give tangible insight for the city policy makers.

Stakeholders

Roles	FVH	CAV
Asset Owner	✓	✓
Asset Consumer	✓	✓
Asset Provider	✓	✓

Use cases

The use cases involved in this demo case are:

- **UC_7_3:** Urban planning energy performance and SECAP targets tracking
- **UC_7_5:** Energy performance optimization at building level
- **UC_7_6:** Energy performance optimization at district level

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Available Data Assets

The data assets that will be used to develop DC 17 are introduced in the next table.

Table 71: Available Data Assets for DC17

Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform
OPEN_9	Local weather data / Helsinki Energy and Climate Atlas data	VTT	The Urban Energy Monitoring and Planning Support App	1st iteration
FI_FVH_1	Temperature	FVH	The Urban Energy Monitoring and Planning Support App	1st iteration
[1] FI_FVH_2	Incoming air temperature	FVH	The Urban Energy Monitoring and Planning Support App	1st iteration
FI_FVH_3	Motor drive setting	FVH	The Urban Energy Monitoring and Planning Support App	1st iteration
FI_FVH_4	Convector water intake temperature	FVH	The Urban Energy Monitoring and	1st iteration

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			Planning Support App	
FI_FVH_5	Visitor counter	FVH	The Urban Energy Monitoring and Planning Support App	1st iteration
FI_FVH_6	Hot water consumption	FVH	The Urban Energy Monitoring and Planning Support App	1st iteration

Energy Applications

The energy applications that will be used to develop DC17 are introduced in the next table.

Table 72: Energy applications to be used within DC17

Energy app name	Component	Input data assets (IDA)	Output data assets (ODA)
Urban Energy Monitoring and Planning Support App	Near Real-Time City Monitoring and Visualization Tool (NRCMV) VTT	Local weather data (JSON) FMI open source Measured energy generation profiles in the area Measured buildings energy consumption profiles in the area	List of new indicators according to NRCMV_4 (For more information about the application, see D7.1 table 13 and D2.7)
Urban Energy	Strategic Urban	As listed in previous table Available Data Assets	Application provides simulation scenarios, not seen as "data asset"

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Monitoring and Planning Support App	Planning Supporter (SUPS) VTT	City SECAP target KPIs as manually entered	

Data Analytics

Not applicable on DC17 and algorithms are part of the NRCMV implementation and described in D7.1 section 3.2.

Hardware Components

The following hardware components are present in this demo case

Table 73 : Hardware components to be used in DC17

Hardware component id	Application	Input data assets (IDA)	Output data assets (ODA)
HW 1	AXIS M3065-V network cameras for counting visitors	N/A	Visitors' count (json) FI-FVH-5

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Workflow

The workflow and sequential diagrams of DC17 are illustrated in the following diagrams.

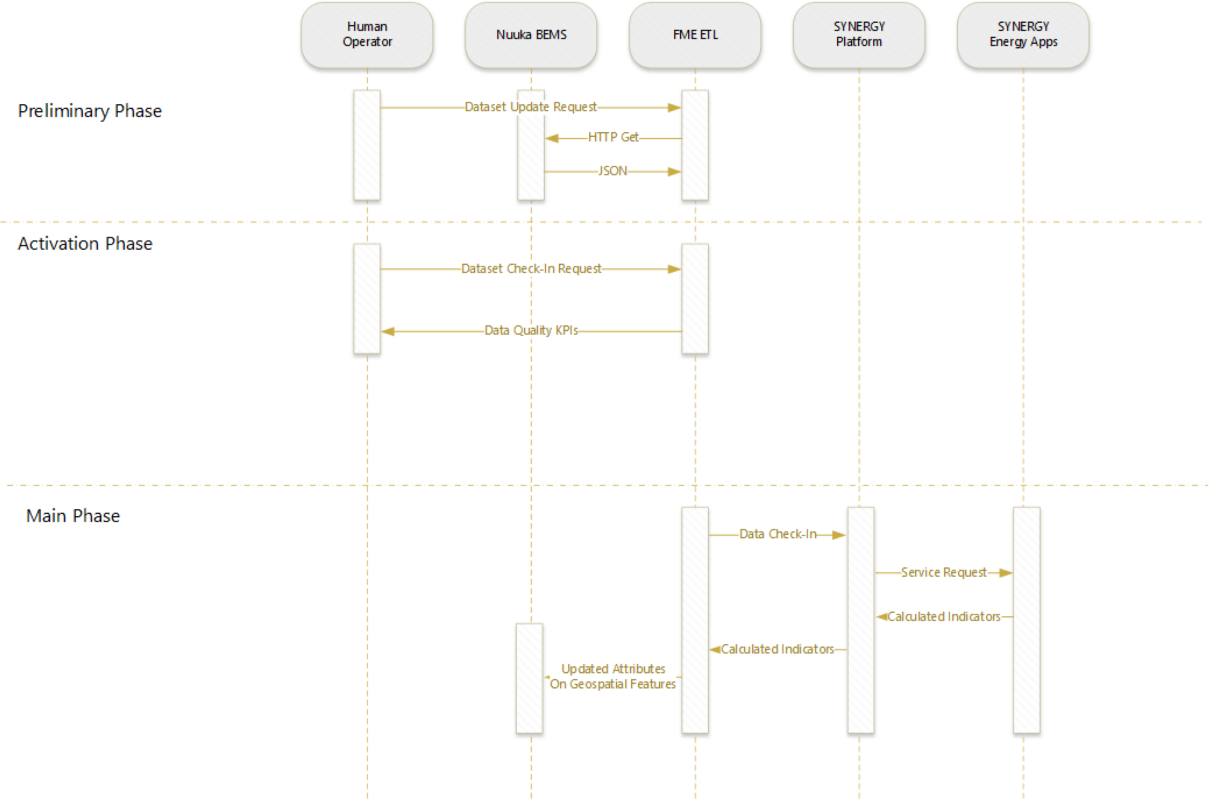

Figure 41: DC17 sequential diagram

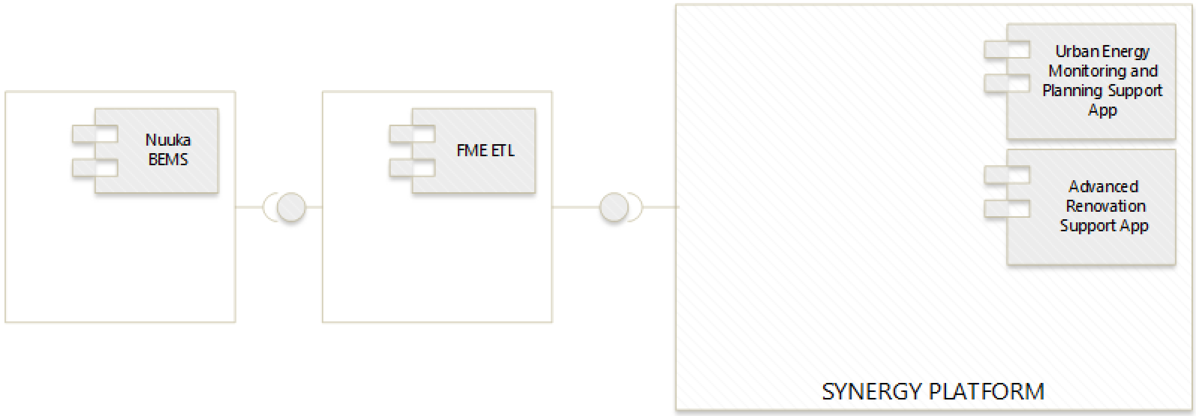

Figure 42: DC17 Workflow flowchart

In the **preliminary phase**, the data origin systems such as the Nuuka Building Energy Management System (BEMS) update or maintain the datasets used as a source to update the SYNERGY energy performance indicators. The **activation phase** is scheduled with rate to be defined according to refresh rates of the source datasets. It is expected that while technically possible and feasible, an update rate of 1/24hours will provide an adequate level of up-to-date awareness for the user. In the **main phase**

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the actual data integration and fusion tasks are performed as part of the ETL workflow: The ETL will fetch the latest datasets, transformation converts and calculates the required values and writer - function writes the output as new or updated attributes to the SYNERGY platform to optionally run some visualizations.

5.4.1.2 Impact KPIs

The main KPIs that will be assessed in demo case 17 are:

- Building energy consumption forecasting accuracy

5.4.1.3 Preliminary Evaluation Plan

The data transformation process is based on an ETL tool used by the city on geospatial data conversions, including the Spatial Data Infrastructure (SDI) and the generation of the INSPIRE download services. The ETL workflow can be designed and triggered manually for preliminary evaluation and then deployed on production stage after the evaluation is completed.

5.4.2 Demo Case 18: Advanced Urban Planning for long-term sustainability targets realization

5.4.2.1 Validation scenario

Description

The Demo Case 18 aims to provide insights for the urban planning stakeholders to realize long-term sustainability targets realization. The DC18 relies on input from DC19 and DC20 together with the intelligence extracted from the urban monitoring analytics tool and the indicator calculation performed in DC17. The workflow and technology stack is identical to DC17. In addition, the Urban Energy Monitoring and Planning Support App (T7.2) will be validated in this demo case.

Objectives

- Objective 1: Provide new insight for the various stakeholders in urban planning to increase awareness on the realization of long-term sustainability
- Objective 2: To support urban planners with appropriate simulation-based tools and enabling intelligence sharing with relevant stakeholders towards realizing mid and long-term commitments with regards to sustainability and energy efficiency.

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- Objective 3: To support city authorities to design alternative urban transformation strategies (optimized energy management, building renovation, interaction of buildings with energy markets, transportation interventions and strategies for EVs penetration) and assess them in an accurate manner to decide on optimal routes to satisfy already declared targets in the city's Sustainable Energy and Climate Action Plan (SECAP
- To enhance urban performance simulation accuracy towards the increasing the effectiveness of relevant optimization strategies.

Stakeholders

Roles	FVH	CAV
Asset Owner	✓	✓
Asset Consumer	✓	✓
Asset Provider	✓	✓

Use cases

The use cases involved in this demo case are:

- **UC_7_3:** Urban planning energy performance and SECAP targets tracking

Available Data Assets

The data assets that will be used to develop DC 18 are introduced in Table 74.

Table 74: Available Data Assets for DC18

Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

OPEN_9	Local weather data / Helsinki Energy and Climate Atlas data	VTT	Urban Energy Monitoring and Planning Support App	1st iteration
FI_FVH_1	Temperature	FVH	Urban Energy Monitoring and Planning Support App	1st iteration
[1] FI_FVH_2	Incoming air temperature	FVH	Urban Energy Monitoring and Planning Support App	1st iteration
FI_FVH_3	Motor drive setting	FVH	Urban Energy Monitoring and Planning Support App	1st iteration
FI_FVH_4	Convector water intake temperature	FVH	Urban Energy Monitoring and Planning Support App	1st iteration

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FI_FVH_5	Visitor counter	FVH	Advanced Renovation Support App	1st iteration
FI_FVH_6	Hot water consumption	FVH	Urban Energy Monitoring and Planning Support App	1st iteration

Energy Applications

The energy applications that will be used to develop DC18 are introduced in the next table.

Table 75: Energy applications to be used within DC18

Energy app name	Component	Input data assets (IDA)	Output data assets (ODA)
Urban Energy Monitoring and Planning Support App	VTT	Local weather data (JSON) FMI open source	The Strategic Urban Planning Supporter (SUPS) does not have output data assets since it is a strategic planning tool and helps with determining the visions for the future.

Data analytics

Not applicable on DC18, algorithms part of the SUPS application deployment as described in D7.1 section 3.2

Hardware Components

The following hardware components are present in this demo case:

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Table 76: Hardware components to be used in DC18

Hardware component id	Application	Input data assets (IDA)	Output data assets (ODA)
HW 1	AXIS M3065-V network cameras for counting visitors	N/A	Visitors' count (json) FI-FVH-5

Workflow

The workflow and sequential diagrams of DC18 are illustrated in the following diagrams.

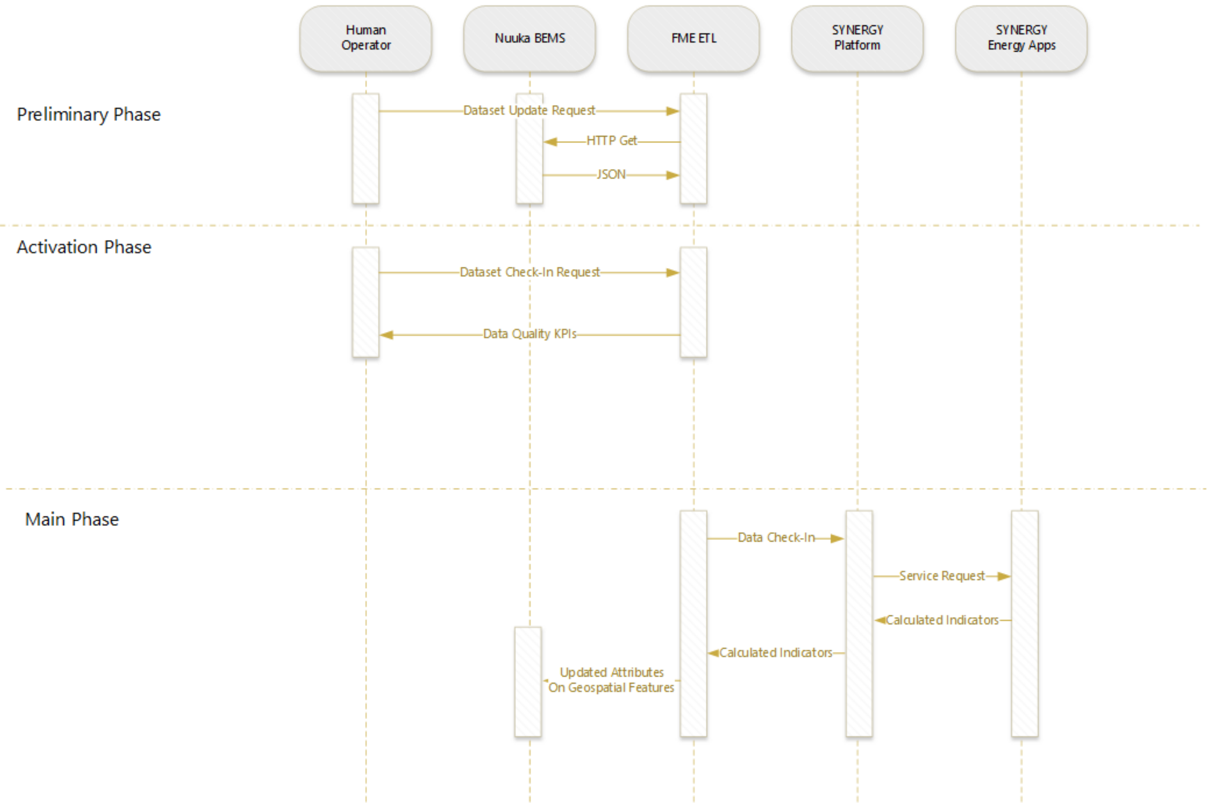

Figure 43: DC18 sequential diagram

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

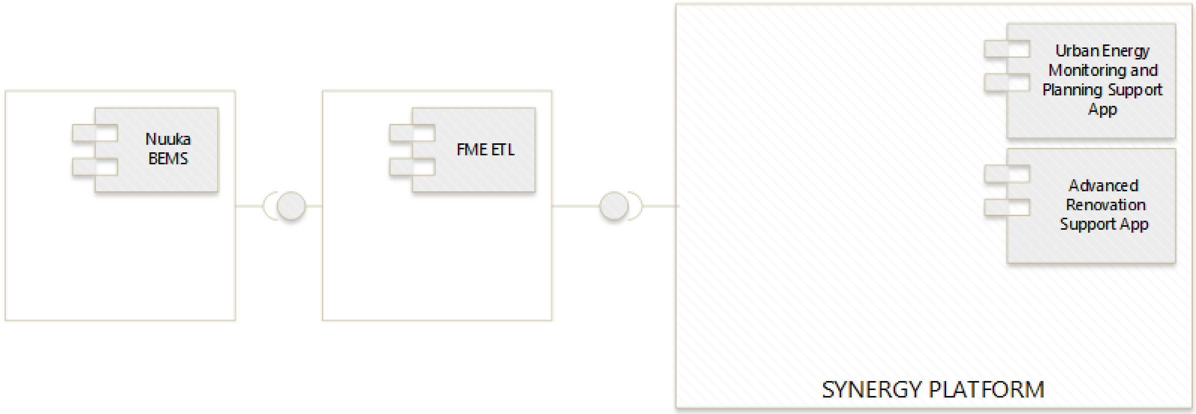

Figure 44: DC18 Workflow flowchart

In the **preliminary phase**, the data origin systems such as the Nuuka Building Energy Management System (BEMS) update or maintain the datasets used as a source to update the SYNERGY energy performance indicators. The **activation phase** is scheduled with rate to be defined according to refresh rates of the source datasets. It is expected that while technically possible and feasible, an update rate of 1/24 hours will provide an adequate level of up-to-date awareness for the user. In the **main phase** the actual data integration and fusion tasks are performed as part of the ETL workflow: The ETL will fetch the latest datasets, transformation converts and calculates the required values and writer - function writes the output as new or updated attributes to the SYNERGY platform to optionally run some visualizations.

5.4.2.2 Impact KPIs

The main KPIs that will be assessed in demo case 18 are:

- Improved support for urban energy planning decision making

5.4.2.3 Preliminary Evaluation Plan

The data transformation process is based on an ETL tool used by the city on geospatial data conversions, including the Spatial Data Infrastructure (SDI) and the generation of the INSPIRE download services. The ETL workflow can be designed and triggered manually for preliminary evaluation and then deployed on the production stage after the evaluation is completed.

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5.4.3 Demo Case 19: Evidence-based renovation support for optimized and accurate energy-efficient design of buildings

5.4.3.1 Validation scenario

Description

In demo case 19 building energy management data from demo sites provided by both Caverion (CAV) and Forum Virium Helsinki (FVH) together with occupants' behaviour and comfort profiles created in WP4 will be used in the Advanced Renovation Support App (T7.1) for pre-analysis and identification of renovation scenarios for the selected demo sites.

Further analysis of the selected renovation scenarios will be done in the Advanced Renovation Support App (T7.1) to identify energy performance outliers and to enable more comprehensive design of renovation approaches and scenarios to achieve highly accurate optimization of anticipated energy performance, renovation project costs and occupants' comfort. The results gathered from this demo case will then be shared with FVH to increase the optimization and accuracy in their urban planning done in demo case 18.

The dataflows and processes of this demo case are described in the section "Workflow".

Objectives

- Objective 1: Significantly reduced building energy performance gap (BEPG) during the design of renovation projects, and thus reduced risks associated with EPC business model
- Objective 2: Facilitating further penetration of the Energy Performance Contracting (EPC) model for ESCOs
- Objective 3: Identified energy performance outliers and enabling further devising of renovation approaches and scenarios to achieve optimal balancing between anticipated energy performance, renovation project costs and occupants' comfort.
- Objective 4: Supporting optimized and accurate urban planning through validation of highly accurate results for the anticipated energy performance of to-be-renovated buildings.

Stakeholders

Roles	FVH	CAV
Asset Owner	✓	✓
Asset Consumer	✓	✓
Asset Provider	✓	✓

Use cases

The use cases involved in this demo case are:

- **UC_7_1:** Increased accuracy in building energy simulation results through the utilization of accurate profiles and schedules of occupants
- **UC_7_2:** Creation of the building energy passport for increasing attractiveness of investments in buildings

Available Data Assets

The data assets that will be used to develop DC 19 are introduced in Table 12

Table 77: Available Data Assets for DC19

Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform
FI_CAV_1	Energy Consumption	CAV	Advanced Renovation Support App	Available
FI_CAV_2	Energy Production (kWh) and Power (W) of PV-System, etc. other RES data	CAV	Advanced Renovation Support App	Available
FI_CAV_3	Outdoor Air Temp	CAV	Advanced Renovation Support App	Available
FI_CAV_4	Illuminance	CAV	Advanced Renovation Support App	Available

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FI_CAV_5	Indoor air temp.	CAV	Advanced Renovation Support App	Available
FI_CAV_6	Supply air temp. setpoint	CAV	Advanced Renovation Support App	Available
FI_CAV_7	AHU measurements	CAV	Advanced Renovation Support App	Available
FI_CAV_8	HVAC system setpoints and related measurement values	CAV	Advanced Renovation Support App	Measurement values available, but HVAC system setpoints will become available after needed CIM updates
FI_CAV_9	Room temperatures	CAV	Advanced Renovation Support App	Available
FI_CAV_10	Supply and return water setpoints for radiators and floor heating	CAV	Advanced Renovation Support App	Available
FI_CAV_11	Indoor air quality	CAV	Advanced Renovation Support App	Available
FI_CAV_12	Air volume	CAV	Advanced Renovation Support App	Available
FI_CAV_13	AHU pressure difference	CAV	Advanced Renovation Support App	Available
FI_CAV_14	AHU heat recovery efficiency	CAV	Advanced Renovation Support App	Not yet available. Waiting for needed CIM updates.
FI_CAV_15	Heating pump related measurements	CAV	Advanced Renovation Support App	Available
FI_CAV_16	Heating pump related specific requirements	CAV	Advanced Renovation Support App	Not yet available. Waiting for needed CIM updates.
FI_CAV_17	Building level energy usage measurements	CAV	Advanced Renovation Support App	Available
FI_CAV_18	DHW and warm water consumption	CAV	Advanced Renovation Support App	Available
FI_CAV_19	Room controller information related values (setpoints,	CAV	Advanced Renovation Support App	Available

	occupancy and air flow)			
FI_CAV_20	Outdoor values (temperature)	CAV	Advanced Renovation Support App	Available
OPEN_9	Local weather data / Helsinki Energy and Climate Atlas data	VTT	Advanced Renovation Support App	Currently on-premises. Will be uploaded to SYNERGY platform before February
FI_FVH_1	Temperature	FVH	Advanced Renovation Support App	1st iteration
FI_FVH_2	Incoming air temperature	FVH	Advanced Renovation Support App	1st iteration
FI_FVH_3	Motor drive setting	FVH	Advanced Renovation Support App	1st iteration
FI_FVH_4	Convector water intake temperature	FVH	Advanced Renovation Support App	1st iteration
FI_FVH_5	Visitor counter	FVH	Advanced Renovation Support App	1st iteration
FI_FVH_6	Hot water consumption	FVH	Advanced Renovation Support App	1st iteration

<u>Energy applications</u>

The energy applications that will be used to develop DC19 are introduced in the next table.

Table 78: Energy applications to be used within DC19

Energy app name	Component	Input data assets (IDA)	Output data assets (ODA)
Advanced Renovation Support App	AI-RDSS AI-boosted renovation decision supporting VTT	Renovation targets, (user input), General building parameters (json) (CAV) Building envelope (json) (CAV) Building heat gains and schedules (csv) (CAV) Renovation product data (VTT) Country level information (VTT) Building energy consumption (csv) (CAV) Local weather data (JSON) FMI open source	Space heating and hot water energy consumption (before renovation, after renovation & renovation related savings) Appliance electricity consumption (before renovation, after renovation & renovation related savings) Space cooling energy consumption (before renovation, after renovation & renovation related savings) Carbon footprint (before renovation, after renovation & renovation related savings). If country level data available

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			Energy cost (before renovation, after renovation & renovation related savings). If country level unit costs available.
Advanced Renovation Support App	IDA-ICE-RAS Detailed level modelling of selected renovation cases VTT	Building envelope (json) (CAV) Building systems (json) (CAV) Local weather data (JSON) (FMI open source)	Space heating and hot water energy consumption (before renovation, after renovation & renovation related savings) Appliance electricity consumption (before renovation, after renovation & renovation related savings) Space cooling energy consumption (before renovation, after renovation & renovation related savings), etc.

<u>Data analytics</u>

The analytics that are expected to be used for the implementation of DC19 are introduced in Table 79.

Data analytics are executed in the SYNERGY Platform.

Table 79: Data analytics to be used within DC19

Data Analytics name	Algorithm	Input data assets (IDA)	Output data assets (ODA)
AI boosted renovation decision support	AI boosted renovation decision support -VTT-	Renovation targets, (user input), General building parameters (json) (CAV) Building envelope (json) (CAV) Building heat gains and schedules (csv) (CAV) Renovation product data (VTT) Country level information (VTT) Building energy consumption (csv) (CAV) Local weather data (JSON) FMI open source	Space heating and hot water energy consumption (before renovation, after renovation & renovation related savings) Appliance electricity consumption (before renovation, after renovation & renovation related savings) Space cooling energy consumption (before renovation, after renovation & renovation related savings) Carbon footprint (before renovation, after renovation & renovation related savings). If country level data available Energy cost (before renovation, after renovation & renovation related savings). If country level unit costs available. -VTT-
Occupants' behaviour and comfort profiles	Occupants' behaviour and comfort profiles -Suite5	Electricity consumption of ACs Ambient related data Electricity data	AC consumption for different comfort levels AC consumption flexibility forecast

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		Season Climate Building type Thermal sensation Thermal sensation acceptability Standard effective temperature Air temperature Relative humidity Air velocity Outdoor monthly air temperature Room temperature HVAC status Setpoint Outdoor temperature Outdoor humidity Electricity consumption Indoor environmental measurements Occupants ID Date Energy consumption value -Suite5	Anomaly detection in household energy consumption Short-term occupants' thermal comfort prediction Occupants' thermal comfort duration prediction Identification of occupants, thermal comfort boundaries HVAC usage short-term prediction Clustering of occupants to identify common features -Suite5

Hardware Components

The following hardware components are present in this demo case:

Table 80: Hardware components to be used in DC19

Hardware component id	Algorithm	Input data assets (IDA)	Output data assets (ODA)
HW 1	*short description of each HW component* *- Responsible Partner*	*Input data asset from SYNERGY Platform to HW component* *(csv, json, graphs, etc.) - Responsible Partner*	*Output data asset from HW component to SYNERGY Platform* *(csv, json, graph, etc.) - Responsible Partner*

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HW1	*Produal TEK NTC 10 Temperature sensor for duct temperature measuring*	*N/A*	*Fresh air temperature, json* *Temperature after heating and cooling coils, json* *-CAV*
HW2	*Produal KLK 100 Humidity and temperature sensor for duct temperature and humidity measuring.*	*N/A*	*Supply air humidity, json* *-CAV*

<u>Workflow</u>

Demonstration and validation activities will be organised through the two respective demo runs (1) **first real-life demo run** and initial evaluation of technical developments and associated impacts (M24-M33) and (2) further optimization the system and roll out of the **second demo-run**, in the frame of the agile and iterative development and implementation process adopted by the project (M34-M42).

Both demo runs consist of three phases - **preliminary, activation, main** as presented in the following. The second demo-run will repeat the main phase of validation to provide the final analysis of the developed application.

The full workflow of the demo case 19 is shown below:

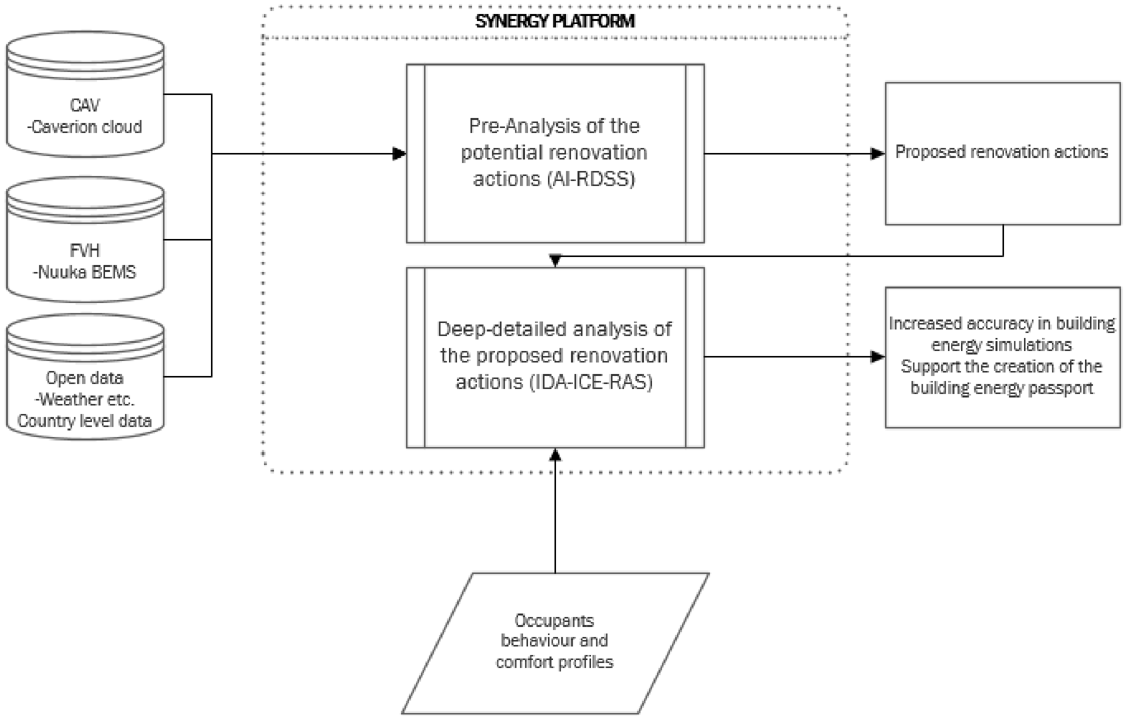

Figure 45: DC19 workflow flowchart

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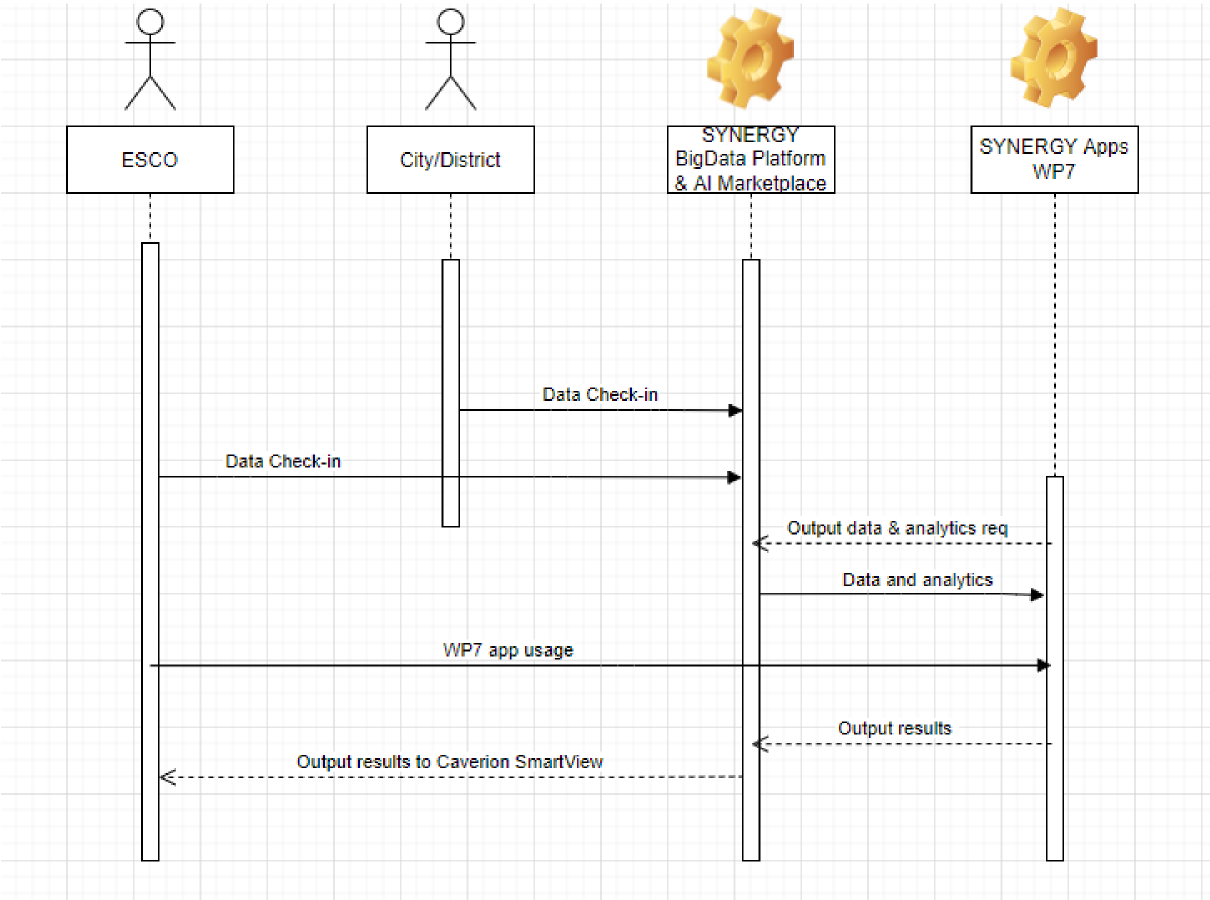

Figure 46 : DC19 sequence diagram

The first demo-run

The first demo run will focus on validating the current (as of M24) functionalities of Advanced Renovation Support App components.

Preliminary phase:

The process starts with the testing of SYNERGY API with sample BMS datasets and ensuring correct mapping. The next step is to finalize all the data check-in jobs for all the datasets needed for the demo case in order to start baseline data collection.

When all data check-in jobs are finalized and data collection is running continuously Suite5 can utilize the data from sensors (temperature, humidity, CO_2, and occupancy), data about control actions performed in HVAC systems (thermostat setpoints, operation mode and other characteristics like fan speed) and sub-metering data about the energy consumption of HVAC systems to create the occupants' behaviour and comfort profiles.

After the creation of the occupants' behaviour and comfort profiles the testing of application data transfer can begin with the data uploaded to the SYNERGY platform. After data transfer has begun the preliminary testing of applications and toolkits can start. After the preliminary testing process the initializing/configuring the apps and data analytics are done to be ready for the activation phase.

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

Activation phase:

The triggering event for the demo case 19 validation scenario is to set renovation targets into the AI-RDSS tool to start the analysis. If no renovation targets are set the process reverts to the baseline data collection part of the preliminary phase. If the renovation targets are set the process will move on to the main phase.

Main phase:

The main phase starts with the preliminary analysis done in the AI-RDSS tool. The toolkit utilizes the occupants' behaviour and comfort profiles together with data assets from SYNERGY platform. The data assets needed for the pre-analysis done in AI-RDSS consists of CAV's, FVH's and open data assets that are listed in section "Available Data Assets".

The process starts with the selection of the renovation targets and basic information set by the user of the tool. After the selection occupants' behaviour and comfort profiles are fetched from the SYNERGY platform APIs.

The user then needs to select one or more renovation actions for the tool to start machine learning of the most important missing model parameters. After the selection the tool will start a calculation loop to calculate the selected renovation scenarios one by one and then stores the results into SYNERGY platform. Additionally, the results can be exported into CAV owned SmartView commercial tool to be used for demonstration purposes.

The output results from the AI-RDSS tool are shown in the respective table of section "Energy Applications". After the results of the AI-RDSS tool are published into SYNERGY platform the deeper analysis in IDA-ICE-RAS can begin.

The data assets needed for the analysis done in IDA-ICE-RAS are shown in the respective table of section "Available Data Assets".

The IDA-ICE-RAS will utilize these data assets together with the results gathered from AI-RDSS tool to perform detailed modelling of the studied building and related pre-selected renovation actions. It will then create a detailed digital twin of the studied building based on the available design parameters and calculate the pre-selected renovation actions. The results are then stored in the SYNERGY platform. Additionally, the results can be exported into CAV owned SmartView commercial tool to be used for demonstration purposes. The results from the IDA-ICE-RAS tool are shown in the respective table of section "Energy Applications".

The results from this validation scenario are used to validate the use cases UC_7_1 and UC_7_2.

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

The second demo-run

The second demo run will repeat the main phase validation of the previous first demo run with the performing further optimization and the final validation of Advanced Renovation Support App components.

Preliminary phase:

The preliminary phase of the second demo run will consist of validation of the required input data assets and making sure that the data transfer from SYNERGY platform is still fully functional.

Activation phase:

The activation phase of the second demo run follows the same procedures as in the first demo run.

Main phase:

The main phase of the second demo run will repeat the main phase of the first demo run but with a focus on validation of the full functionalities of the Advanced Renovation Support App components.

5.4.3.2 Impact KPIs

The main KPIs that will be assessed in demo case 19 are:

- Building energy consumption forecasting accuracy
- Time saving to select the required renovation actions
- Cost savings due to renovation actions

5.4.3.3 Preliminary evaluation plan

The evaluation will validate the results from this demo case using the three KPIs mentioned above. The baseline estimation will be performed in the beginning of the preliminary phase of the first demo run. The three values will be calculated in the KPIs can be used and are measurable in both evaluation rounds, but the amount of pilot sites included in each round will differ. For the first round of evaluation the aim is to validate the pre-analysis results done in AI-RDSS for multiple pilot sites, but for the deeper analysis done in IDA-ICE-RAS the aim is to validate the results using only one of the pilot sites. For the second round of evaluation, the pilot sites used will be broadened to gather more valuable information from different pilot sites and the results gathered will be compared to the desired values set at the beginning of the project and to the results gathered in the first evaluation round.

The evaluation follows a structure where firstly, the information needed for the calculation of the related KPIs will be collected by the responsible partners.

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Secondly, the results from the operation of the Advanced Renovation Support App will be gathered and KPIs are calculated.

Lastly, the results are compared to the baseline estimation, thus measuring the Apps potential benefits.

The above structure will be used in both evaluation rounds.

5.4.4 Demo Case 20: Holistic Real-time Facility Energy Management Optimization

5.4.4.1 Validation scenario

Description

In demo case 20 different building energy management data from Caverion (CAV), Forum Virium Helsinki (FVH) are offered to the SYNERGY platform. The data provided will be used as input to conduct detailed analysis and optimization of building assets, using Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance App.

In the demo case the data will be utilized in Facility Management Energy analytics Self-Consumption Optimization & Predictive Maintenance Application to support the creation of flexibility control strategies, through human-centric control of major building loads, to maximize self-consumption of the demo sites, and to enable real-time energy performance certification through the use of BL-EPOM, DL-EPON, eDEC-CE and SRI-CE tools. Similarly, the HVAC-PMS tool for predictive maintenance is utilized to enable accurate fault diagnosis and characterization over critical systems and equipment, probability assessment of fault occurrence, early prediction of faults and to facilitate increased reliability and efficiency of building technical assets. The real-time monitoring of HVAC and building conditions and the displaying of results utilizes the already existing upper-level building monitoring platform SmartView, which will be provided by Caverion.

Data retrieved from the SYNERGY platform, together with manual data input will be used to calculate the energy performance indicators associated with the Display Energy Performance certificate and Smart Readiness Indicator calculation engines.

The results gained from demo case 20 will be shared with FVH to increase optimization and accuracy in their urban planning done in demo case 18.

The dataflows and processes of this demo case are described in the section "Workflow".

Objectives

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The objective of this Demo case is to support the optimization of building assets, through real-time energy consumption optimization, self-consumption maximization, predictive and real-time energy performance certification and by introducing highly effective extrinsic motivation means towards pushing occupants to further optimize their energy behaviours. More specifically:

- Objective 1: To enhance detailed analysis and optimization of building assets, through near real-time energy consumption optimization by enabling of human-centric control of major building loads
- Objective 2: To support detailed analysis and optimization of building assets, through self-consumption maximization
- Objective 3: To enhance the predictive maintenance, through enabling accurate fault diagnosis and characterization over critical systems and equipment, probability assessment of fault occurrence, early prediction of faults, and through facilitating increased reliability and efficiency of building assets.
- Objective 4: To provide the detailed analysis and optimization of building assets, through near real-time energy performance certification

Stakeholders

Roles	CAV	FVH
Asset Owner	✓	✓
Asset Provider	✓	✓
Asset Consumer	✓	✓

Use cases

The use cases involved in this demo case are:

- **UC_7_4:** Predictive management at building level
- **UC_7_5:** Energy Performance optimization at building level
- **UC_7_6:** Energy Performance optimization at district level

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- **UC_7_7:** Real-time dynamic assessment of building energy performance through eDECs
- **UC_7_8:** Advanced Energy performance certificate with smart readiness indicators

Available Data Assets

The data assets that will be used to develop DC 20 are introduced in the next table.

Table 81: Available Data Assets for DC20

Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform
FI_CAV_1	Energy Consumption	CAV	Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance App	Available
FI_CAV_2	Energy Production (kWh) and Power (W) of PV-System, etc. other RES data (optional)	CAV	Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance App	Available
FI_CAV_3	Outdoor Air Temp	CAV	Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance App	Available

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FI_CAV_4	Illuminance	CAV	Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance App	Available
FI_CAV_5	Indoor air temp.	CAV	Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance App	Available
FI_CAV_6	Supply air temp. setpoint	CAV	Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance App	Available
FI_CAV_7	AHU measurements	CAV	Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance App	Available
FI_CAV_8	HVAC system setpoints and related (specific HVAC machines)	CAV	Facility Management Energy Analytics, Self-Consumption Optimization &	Measurement values available, but HVAC system setpoints will become available

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	(measurement values		Predictive Maintenance App	after needed CIM updates
FI_CAV_9	Room temperatures	CAV	Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance App	Available
FI_CAV_10	Supply and return water setpoints for radiators and floor heating	CAV	Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance App	Available
FI_CAV_11	Indoor air quality	CAV	Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance App	Available
FI_CAV_12	Air volume	CAV	Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance App	Available
FI_CAV_13	AHU pressure difference	CAV	Facility Management Energy Analytics, Self-	Available

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			Consumption Optimization & Predictive Maintenance App	
FI_CAV_14	AHU heat recovery efficiency	CAV	Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance App	Not yet available. Waiting for needed CIM updates.
FI_CAV_17	Building level energy usage measurements	CAV	Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance App	Available
FI_CAV_19	Room controller information related values	CAV	Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance App	Available
FI_CAV_20	Outdoor values	CAV	Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance App	Available

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OPEN_9	Local weather data	CAV/VTT	Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance App	Currently available on-premises. Should be added to SYNERGY platform by February.
Static library	Energy consumption benchmarks	VERD	eDEC - enhanced Display Energy Certificates) Calculation Engine	1st iteration
Static library	Energy consumption benchmark profile per building type	VERD	eDEC - enhanced Display Energy Certificates) Calculation Engine	1st iteration
User input	Building characteristics	CAV	eDEC - enhanced Display Energy Certificates) Calculation Engine	1st iteration
FI_CAV_1	Electricity consumption readings	CAV	eDEC- enhanced Display Energy Certificates) Calculation Engine	1st iteration
FI_CAV_2	Electricity production from RES	CAV	eDEC -	1st iteration

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			enhanced Display Energy Certificates) Calculation Engine	
Static library	Grid emission factor	VERD	eDEC - enhanced Display Energy Certificates) Calculation Engine	1st iteration
OPEN_2	Daily temperature	VERD	eDEC - enhanced Display Energy Certificates) Calculation Engine	1st iteration
User input	Methodology type	CAV	SRI_CE - Smart Readiness Indicator) Calculation Engine	1st iteration
User input	Country	CAV	SRI_CE - Smart Readiness Indicator) Calculation Engine	1st iteration
User input	Building type	CAV	SRI_CE - Smart Readiness Indicator) Calculation Engine	1st iteration

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User input	Service functionality	CAV	SRI_CE - Smart Readiness Indicator) Calculation Engine	1st iteration
Static library	SRI methodology weightings factors	VERD	SRI_CE - Smart Readiness Indicator) Calculation Engine	1st iteration

Energy applications

The energy applications that will be used to develop DC20 are introduced in the next table.

Table 82: Energy applications to be used within DC20

Energy app name	Component	Input data assets (IDA)	Output data assets (ODA)
Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance App	HVAC-PMS: The component will support recognizing building technical system malfunctions, inefficiencies and optimization possibilities. VTT/CAV	Building energy consumption (csv/json, CAV/FVH) Local weather data (json, open data source) AHU related measurements (csv/json, CAV) Space related measurements (csv/json, CAV/FVH) Building envelope related measurements (csv/json, CAV) Building technical system data (csv/json, CAV)	Calculated AHU heat recovery efficiencies and comparisons to set limits (json, CAV) Evaluated filter functionalities (json, CAV) Evaluated command and state conflicts of fans and frequency controllers (json, CAV) Evaluated heat coil valve actuator oscillation (json, CAV) Evaluated wated temperature and actuator or heat coil valve conflicts (json, CAV)

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			Evaluated heating network pressures and temperatures in comparison to limits and setpoints (json, CAV) Evaluated heating network valve oscillation (json, CAV) Evaluated heating network pump command, speed and state conflicts (json, CAV) Evaluated airflow in comparison to damper functions (json, CAV) Evaluated supply and exhaust airflow functions and comparison (json, CAV) Evaluated CO2 levels in comparison to damper and airflow functionalities and control (json, CAV) Space/cooling malfunctions (errors for maintenance) (json, VTT) Space heating/cooling inefficiencies (% of original efficiency) and optimization possibilities for maintenance (json, VTT) Air handling unit malfunctions (errors for maintenance) (json, VTT) Air handling unit inefficiencies (% of original efficiency) and optimization possibilities for maintenance. (json, VTT)
Facility Management Energy Analytics, Self-Consump	BL-EPOM: Calculation of the operation profile of manageable systems that maximize self-	PV & wind generator characteristics Building fixed data and characteristics Storage system characteristics	Control strategies / Optimal operation setpoints - CIRCE-

tion Optimization & Predictive Maintenance App	consumption and reduce energy costs according to the expected building energy demand and generation and its systems state. -CIRCE	EV and EV charging spot characteristics Grid connection characteristics Other costs Temperature setpoint for HVAC Storage system data EV batteries system data Grid connection availability PV & wind generators availability Weather data Building internal temperature and building data.	
Facility Management Energy Analytics, Self-Consumption Optimization & Predictive Maintenance App	DL-EPOM: Calculation of the operation profile of manageable systems that maximize self-consumption and reduce energy costs according to the expected district energy demand and generation and its systems state. -CIRCE	Electric grid between buildings characteristics PV & wind generator characteristics Storage system characteristics EV and EV charging spot characteristics Grid connection characteristics Other costs Temperature setpoint for HVAC Storage system data EV batteries system data Grid connection availability PV & wind generators availability Weather data Building internal temperature and building data	Control strategies / Optimal operation setpoints -CIRCE-

eDEC: enhanced Display Energy Certificates) Calculation Engine	App deliver dynamic certificates of building energy performance in variant resolutions (e.g. annual, monthly, daily), for the building as a whole or per designated zone. -VERD	Energy consumption benchmarks Energy consumption benchmark profile per building type Building characteristics (building type, floor area, number of zones, area per zone) Electricity consumption readings Electricity production from RES Grid emission factor Daily temperature -VERD/CAV-	DEC class per zone per HH interval -VERD-
SRI-CE: Smart Readiness Indicator) Calculation Engine	App will deliver the "Smart-Readiness" assessment of a building, by calculating the capability of the building to a) apply energy savings techniques b) respond to user needs and c) offer services to the grid. The tool will utilize static building data and benchmark	Methodology type Country Building type Service functionality level SRI methodology weighting factors -VERD-	Impact factor per area of interest Smart Readiness Indicator percentage SRI class indicator (A, B…etc.) -VERD-

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	values (drawn from the SYNERGY platform) and will calculate various indicators (disaggregated and building total) as per the SRI methodology. -VERD		

Data analytics

The analytics that are expected to be used for the implementation of DC20 are introduced the next table. Data analytics are executed in the SYNERGY Platform.

Table 83: Data analytics to be used within DC20

Data Analytics name	Algorithm	Input data assets (IDA)	Output data assets (ODA)
Short-term Portfolio-level HVAC demand Energy forecasts	Short-term Portfolio-level HVAC demand Energy forecasts	Weather data Building internal temperature [ºC] Building location (latitude and longitude) HVAC consumption [kW] HVAC operation mode [cooling / heating] Building occupancy -CIRCE	HVAC demand model -CIRCE

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Short-term PV & wind forecasts	Short-term PV & wind forecasts	Maximum and minimum power of solar and/or wind generation systems (kW) Building location (latitude and longitude) -CIRCE	Short-term PV & wind forecasts -CIRCE
Energy prices forecasts	Energy prices forecasts	Extra cost for consumed power (€/kW*year) -CIRCE	Energy prices forecasts -CIRCE
Short-term EV-forecasts	Short-term EV-forecasts	Maximum charging and discharging power (kW) Charging and discharging efficiency (%) EV batteries capacity (kWh) Maximum and minimum recommended SoC (%) EV batteries expected life (cycles) EV batteries cost (€/kWh) EV departure SoC (%) Number of EV charging points EV current SoC (%) Charging point availability (0 or 1) EV availability (0 or 1) -CIRCE	Short-term EV-forecasts -CIRCE
Short-term weather forecasts	Short-term weather forecasts	Weather data -CIRCE	Short-term weather forecasts -CIRCE
Short-term building forecasts	Short-term building forecasts	Contracted power (kW) Maximum selling power (kW)	Short-term building forecasts -CIRCE

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		Grid connection availability (0 or 1) Building internal temperature HVAC consumption HVAC operation mode (Cooling/heating) Building occupancy Defferable load usage period Deferrable load profile -CIRCE	
Weather normalisation	Weather normalisation	Weather data Number of degree days in the demo country -Verd	Generic weather normalised benchmark load profiles -Verd
Recognition of malfunctions	Recognition of malfunctions	Building energy consumption Local weather data Air handling unit related measurements Space related measurements Building envelope measurement -CAV-	Recognized building and space heating/cooling malfunctions, inefficiencies and optimization possibilities. -VTT-
Calculation and evaluation of AHU functionalitie s	Calculation and evaluation of AHU functionalities	AHU sensor metering and control data (data on-remises) -CAV	Calculated AHU heat recovery efficiencies and comparison to set limits Evaluated AHU heat valve functionalities Evaluated filter functionalities

			Evaluated command and state conflicts of fans and frequency controllers Evaluated heat coil valve actuator oscillation Evaluated water temperature and actuator or heat coil valve conflicts
Calculation and evaluation of heating network functionalities	Calculation and evaluation of heating network functionalities	Heating network metering and control data -CAV-	Evaluated heating network pressures and temperatures in comparison to limits and setpoints Evaluate heating network valve oscillation Evaluated heating network pump command, speed and state conflicts -CAV, VTT-
Calculation and evaluation of room airflow functionalities	Calculation and evaluation of room airflow functionalities	Metering and control data from BMS -CAV-	Evaluated airflow in comparison to damper functions Evaluated supply and exhaust airflow functions and comparison Evaluated CO2 levels in comparison to damper and airflow functionalities and control -CAV, VTT-

Hardware Components

The following hardware components are present in this demo case:

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Table 84: Hardware components to be used in DC20

Hardware component id	Algorithm	Input data assets (IDA)	Output data assets (ODA)
HW1	Produal TEK NTC 10 Temperature sensor for duct temperature measuring	N/A	Fresh air temperature, json Temperature after heating and cooling coils, json -CAV
HW2	Produal KLK 100 Humidity and temperature sensor for duct temperature and humidity measuring.	N/A	Supply air humidity, json -CAV

<u>Workflow</u>

The demonstration and validation activities will be organised through the two respective demo runs (1) first real-life demo run and initial evaluation of technical developments and associated impacts (M24-M33) and (2) further optimization of the system and roll out of the second demo-run, in the frame of the agile and iterative deployment and implementation process adopted by the project (M34-M42).

The both demo-run consist of three phases (preliminary, activation, main) as presented in the following. The second demo-run will repeat the first demo run and validation to provide the final analysis of the developed applications.

First demo-run

<u>Preliminary phase:</u>

The process starts with the testing of SYNERGY API with sample BMS datasets and ensuring correct mapping to ensure that the next step will go smoothly. The next step is to finalize all the data check-in jobs for all the datasets needed for the demo case to start baseline data collection.

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When all the data check-in jobs from the related partners are finalized and continuous data collection is running, testing the applications data transfer with the data already uploaded into the SYNERGY platform can begin.

After application data transfer has been successfully tested the preliminary testing of applications and toolkits can start. After the preliminary testing process the initializing/configuring the apps and data analytics are done for the applications to be ready for the activation phase.

Activation phase:

The triggering event for the validation scenario is different for all the energy applications of the demo case 20. The HVAC-PMS tool needs to be initialized and continuous data collection with necessary amounts of history data needs to be available to enable the usage of HVAC-PMS tool. The eDEC-CE and SRI-CE tools need the required user inputs to start the calculation in the toolkit. BL-EPOM and DL-EPOM tools need to be initialized by selecting the buildings to be optimized and selecting the optimization schedule to start the optimization.

If no actions mentioned in the activation phase are taken the process reverts to the continuous data collection of the preliminary phase.

Main phase:

The main phase has different functions and procedures for all the energy applications, but the process is the same. In this phase the energy applications are ran and their functionalities are tested and validated through tracking and utilization of the KPIs associated with this demo case. The results from the use of the applications are compared to the original situation of the demo site before the implementation of the applications.

HVAC-PMS

The main phase for the HVAC-PMS starts with the initialization of the tool. The tool utilizes data asset inputs from the SYNERGY platform and visualizes the results to the end-user through the GUI. The data assets needed for the HVAC-PMS tool consists of CAV's and open data assets that are shown in section "Available data assets".

After the continuous data collection and related data storing is established, the platform integrated analytics will start analysing various datasets against the needs and requirements of the occupants and visitors or historical performance of the specific building technical systems.

Simultaneously, the data will be utilized firstly to train the digital twin and neural network models in the SYNERGY platform and when learned, the models will be utilized for detecting building system related malfunctions, inefficiencies, and optimization possibilities. The results are published into the SYNERGY platform. Simultaneously, the results can be exported into CAV owned SmartView commercial tool to be used for demonstration purposes. The outputs of the HVAC-PMS tool are in section “Energy applications” The results from HVAC-PMS are used to validate the use case UC_7_4.

BL/DL-EPOM

The process for the BL-EPOM and DL-EPOM tools starts by the call made by user. The user executes the application, and the next three main steps are made by the tool:

1. The tool gathers and generate all the required information by calling the SYNERGY platform API
    i. This information consists of building fixed data and other characteristics and variable data and forecasts made by the analytics
2. Next, the algorithm of the tool will be executed once all the required information has been gathered. The algorithm is launched in three steps
    i. The pre-processing will adapt the inputs coming from SYNERGY platform to the optimization algorithm
    ii. The module will launch the configuration to decide the optimization horizon.
    iii. Lastly, the tool will start the post-processing to adapt the results of the optimization if needed.
3. The module will publish the outputs on to the SYNERGY platform using a predefined API
    i. Outputs are the operation set points for the manageable systems in proposed optimization horizon

The data input and output assets of this tool are shown in section “Available Data Assets”

The data analytics used in the BL/DL-EPOM tools are listed in section “Data Analytics”

The results from this validation scenario are used to validate the use cases UC_7_4, UC_7_5, UC_7_6, UC_7_7 and UC_7_8.

eDEC-CE

eDEC-CE tool will dynamically calculate the energy performance indicators associated with the Display Energy Performance certificate for the building in review. The tool will utilize field data of the building, static building data and benchmark values and user inputs if some of the required data is not available in the SYNERGY platform. The tool will upload the user inputs made into the SYNERGY platform for future use.

The main phase starts by the selecting the building the user wants to analyse. After selecting the building, the user needs to provide all the required inputs that were not available in the SYNERGY platform. Simultaneously the user will also need to upload a top view image of the building which will then be transformed to a schematic diagram by the tool for the user to define the corners of the provided zones for a visualisation of the building's zones.

After all the required inputs and actions have been made the user can submit the information and the tool will begin calculating using the inputs.

After the calculations the user can download a report of the results.

The data inputs and outputs for the tool are shown in section "Energy Applications"

The data analytics used in the eDEC-CE tool are listed in section "Data analytics"

- Weather normalisation

SRI-CE

The SRI_CE tool will deliver the Smart-Readiness assessment of a selected building. The tool will utilize static building data and benchmark values that are drawn from the SYNERGY platform and use them to calculate various indicators associated with the SRI methodology.

The toolkit's main phase works similarly to the eDEC-CE tool as the user will start the phase by selecting the building he/she wishes to analyse. After selecting the building, the user is asked to provide inputs to assess the smart readiness of the building. After all the inputs are made by the user the user is shown the outputs of the calculation and given a possibility to download the outputs as a pdf file.

The data inputs and outputs for the tool are shown in section "Energy applications"

Second demo-run

The second demo run will repeat the main phase validation of the previous first demo run together with further optimization and final analysis of the applications.

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

Preliminary phase

The preliminary phase of the second demo run will consist of validation of the required input data assets and making sure that the data transfer to and from SYNERGY platform is still functional.

Activation phase

The activation phase of the second demo run follows the same procedures as in the first demo run.

Main phase

The main phase of the second demo run will repeat the main phase functions of the first demo run but by focusing on further optimization of the applications using the results gathered from the first demo run. The second demo run will end with the final analysis and validation of the applications functionalities.

DC20 workflows are summarized in the workflow flowchart below:

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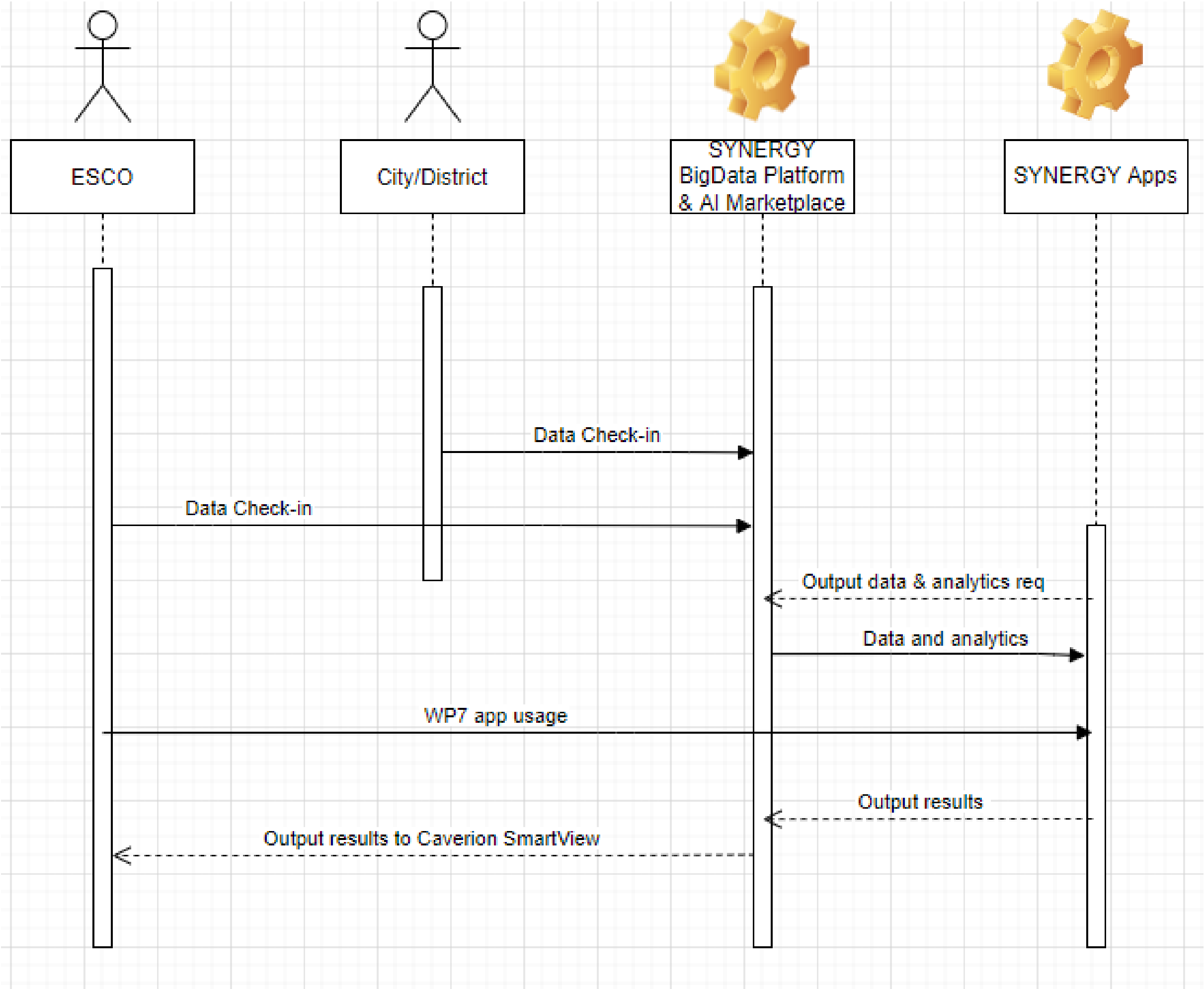

Figure 47: DC 20 sequential diagram

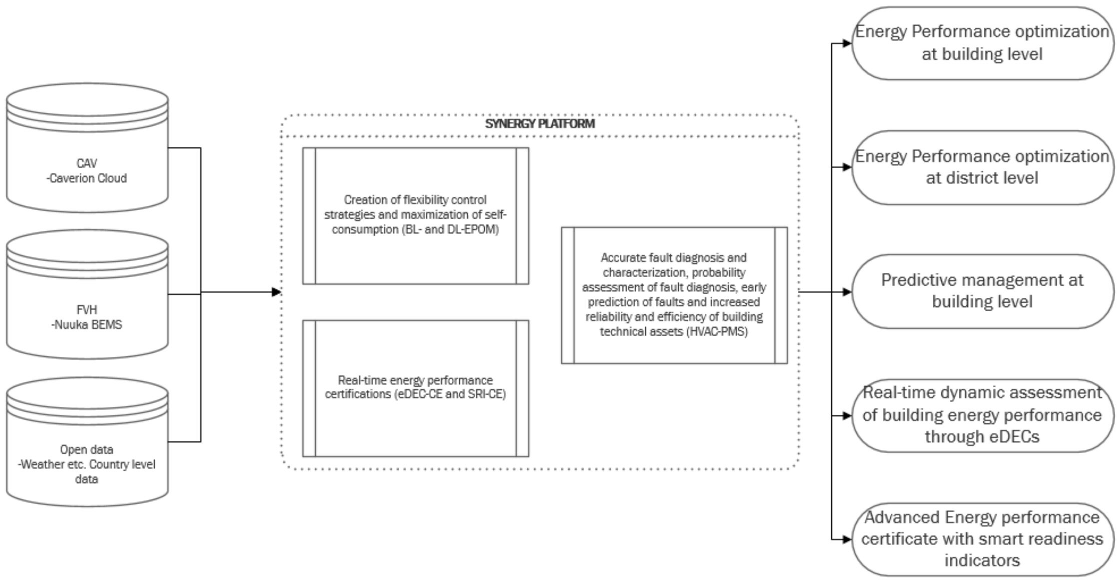

Figure 48: DC 20 workflow diagram

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5.4.4.2 Impact KPIs

The main KPIs that will be assessed in demo case 19 are:

- Peak load demand reduction
- Energy Savings (storage driven/ RES driven)
- Energy Savings (storage driven/ RES driven)
- Energy rating of the building
- Building's total renewable generation
- Energy savings on site for the building
- Flexibility for the grid and storage for the building
- Comfort for the building
- Convenience for the building
- Health & wellbeing for the building
- Maintenance & fault prediction for the building
- Information to occupants for the building
- SRI of the building

5.4.4.3 Preliminary evaluation plan

The evaluation will validate the results of this demo case using the 13 KPIs mentioned in the section above. The KPIs are compared to the demo sites normal operation before the implementation of the SYNERGY applications and the evaluation follows a structure where firstly, the information needed for the calculation of the related KPIs is collected by the responsible partners.

Secondly, the results from the operation of the different applications are gathered and the selected KPIs are calculated. Lastly, the results are compared to the values before the implementation of the SYNERGY applications, thus measuring the applications potential and benefits in real operation.

The above structure will be used in both demo runs.

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5.5 Evaluation in Croatian Demo

5.5.1 Demo Case 21: Self-Consumption Optimization for Energy Poverty Alleviation and Sustainable Local Energy Communities

5.5.1.1 Validation scenario

Description

In this demo case, the focus is promoting the value of self-organized local energy communities for obtaining economic and sustainability benefits, primarily through maximizing self-consumption from own RES. This effort is in line with the net zero strategy of Krk island, adopted in 2010 and updated several times since, including the 2020 update that brought Smart City development strategy to City of Krk. Recent efforts include strong electrification of mobility.

This demo case is built around the idea that the digital progress should not be creating a divide between “haves” and “have nots” so that smart and more efficient energy is in reach of the local community. The sustainable angle has to be observed from community level for two reasons: fully optimizing a single prosumer may not translate into community-level benefits, and there is an additional challenge faced in Krk is the seasonality linked to tourism (e.g. only about a third of the housing objects on the island are occupied throughout the year). Without considering the strong seasonality, conclusions could be misleading.

The principal data sources for this pilot come from Smart Island Krk (SIK) and the Ponikve (KRK) group of municipal utility companies, owned by 7 municipalities at the island of Krk. This includes the solar power plant data, facility data, and public illumination data (as a proxy for a comparatively large communal consumer). Considering the market data and weather data, these are available from external sources. Besides the year-long data assets used for extrapolation, two demo runs are envisioned – one in colder winter months, and one in peak summer season. To appropriately cover seasonality in the demand, other data are used too, however the two demo runs are still needed.

This demo case and Croatian pilot are somewhat specific as although not many partners are involved in the demo, there is a quite multifaceted role of SIK and KRK: they are in parallel a leader of local energy community, energy producer, and the eventual flexibility aggregator. Clearly, In the future it is quite reasonable to envision that these roles will be played by different entities – and this is visible in the final objective of building a business model based on collected data and analyses.

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Finally, for the demo case overall, it is assumed the legal framework in Croatia will support the aggregation fully. This is currently not the case: the legal framework is still emerging and there are technical limitations in the law that might reduce the viability of solutions proposed by Demo Case 21. The Law on Electric Energy Markets issued in October 2021 (*Zakon o tržištu električne energije*, NN 111/21, October 22, 2021) in its Article 26 stipulates that the aggregation is only possible if all the participants are connected to the same distribution substation feeder. However, the bylaws of this law are only expected to enter into force in July 2022 and there is a quite notable public debate, including stakeholders from Krk local community. In order to focus on the technical issues, the assumption is taken that the legal limits will no longer be an issue – i.e. the evaluation focuses on technical issues primarily. The following validation scenarios are therefore considered:

- Validation Scenario 1: Required data correctly available to the SYNERGY platform
- Validation Scenario 2: Flexibility and local consumption assessment using SYNERGY analytics and energy applications
- Validation Scenario 3: Assessment of self-consumption
- Validation Scenario 4: Confirmation of validity of results during the year given the seasonal variations in resource availability

Objectives

- Objective 1: Unlock the currently available but siloed data, release the data from the siloes and ingest the data into the SYNERGY platform, preferably in an active fashion (i.e. without the need for manual data conversion)
- Objective 2: Enable local community data analytics and sharing via the SYNERGY platform to enable the emergence of new business models such as local flexibility aggregation
- Objective 3: Evaluate the current state of self-consumption and energy poverty alleviation
- Objective 4: Simulate the behaviour with the established local aggregation and derive the principal management conclusions from the analysis results on the self-consumption maximization and energy poverty alleviation
- Objective 5 – Derive sustainable business models for local communities based on the analysis in Objectives 3 and 4.

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Considering the relation of objectives to the validation scenarios:

- Objective of VS1: Making the currently siloed and closed data available as data assets to be uploaded to the SYNERGY platform
- Objective of VS 2: Energy applications can use the available data to deliver results (with preliminary data assets); with offline and real time data assets
- Objective of VS 3: Assessment of the local consumption share and flexibility provisioning
- Objective of VS 4: Confirm the assumptions from demo run 1 with the actual data gathered from demo run 2, and run another round of simulations.

Stakeholders

As stated previously, the Krk partners have a multifaceted role in this demo case and it is expected new legal entities will emerge in the future (once the legal framework and business cases are fully established). Also, the stakeholders below represent the status as of December 2021 – with reorganizations in Ponikve Group planned for 2022, SIK will gradually take over duties from Ponikve Eko otok Krk.

Role	Ponikve Eko otok Krk	Smart Island Krk	Končar
Data owners	✓	✓	
Data provider	✓		
Data consumer	✓	✓	
Data broker	✓	✓	
Data scientists	✓	✓	
Data management and services provider		✓	✓

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Use Cases

The selection of use cases reflects the primary goal – to maximize local consumption in order to reduce poverty (UC_6_4), then configure the VPP so that the ancillary services to the grid can be offered as additional income source in challenging seasonal conditions both in summer and winter (in winter many assets are unavailable and disconnected, while in summer the consumption is comparatively higher) through the UC_6_5. Finally, as a way to manage the local community and provide equal opportunities the UC_7_8 is considered as a source of smart readiness and energy performance indicators.

- **UC_6_3:** Retailer portfolio analytics towards the extraction of useful insights
- **UC_6_4:** Flexibility segmentation, classification and clustering
- **UC_6_5:** VPP configuration for the provision of ancillary services to the grid
- **UC_7_8:** Advanced Energy performance certificate with smart readiness indicators

Available Data Assets

As stated in the introduction – for most data the responsible partner is the island of Krk, however their role in the demo case is multifaceted. Challenges caused some delay in setting up the hardware configuration so most of the data, as of December 2021, are only partially available in static form and no data is yet available through an API-based connection.

The data assets that will be used to develop DC 21 are introduced in Table 12.

Table 85: Available Data Assets for DC21

Data Asset	Description	Data Asset Owner/ Provider	Data Asset Consumer (Application)	Status in SYNERGY Platform
HR_KRK_1	Active Power Production (kW)	KRK	Flexibiliy segmentation and analysis of ancillary services; Matching with local consumption:	All assets: Available in exported form. Expected fulyl operational API-

			Portfolio Analytics and Management, Personalized Energy Analytics	based connection via data gateway in M25-M27
HR_KRK_2	Reactive Power Production (kVAr)	KRK	Same as above	
HR_KRK_3	Active Power Production (kW)	KRK		
HR_KRK_4	Reactive Power Production (kVAr)	KRK		
HR_KRK_5	Energy Production (kWh)	KRK		
HR_KRK_6	Electric vehicle charging station (power)	KRK		
HR_KRK_7	Electric vehicle charging station energy (kWh)	KRK		
HR_KRK_8	Philips CityTouch Public Illumination system	KRK		

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HR_KRK_9	Public illumination metering data	KRK		
HR_KRK_10	Smart meter own consumption - impulse readout, DLMS readout or API readout (own, no DSO involved)	KRK		
HR_KRK_11	Smart meter own consumption - indirect data gathered via DSO	KRK		
HR_KRK_12	Vehicle tracking and corresponding fuel costs	KRK		
HR_KRK_13	Garbage disposal container level control	KRK		
HR_KRK_14	End-user waste disposal level tracking	KRK		
HR_KRK_15	Ambient and other data from Zipato smart home monitoring systems	KRK		

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Hardware Components

The following hardware components are present in this demo case:

Table 86: Hardware components for DC21

Hardware component id	Description	Input data assets (IDA)	Output data assets (ODA)
KRK HW 1	(Industrial) computer and corresponding equipment – required to unlock the data assets of SCADA	N/A	ALL Treskavac 1 and 2 PV related data assets
KRK HW 2	Server equipment in Ponikve headquarters	Raw format of all KRK data assets	This hardware equipment serves as a gateway interfacing to SYNERGY. This makes it much easier to debug It runs on the same equipment where KRK local instance of the platform will run.

Data analytics

The data analytics that will be used to develop DC 21 are introduced in Table 87.

Table 87: Available Data Assets for DC21

Data Analytics name	Description	Input data assets (IDA)	Output data assets (ODA)
Aggregate Community (Portfolio-level) Imported Energy	Provide aggregated metrics for further analytics and exposure towards energy pricing at the community (portfolio) level	Customer imported energy	Community level imported energy (Equivalent to portfolio-level)

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Build a model to synthesize yearlong consumption characteristics from incomplete dataset and seasonality input data	Create and train a model that extrapolates the year-long situation from a limited time real data and year-long data from other sources	Total locally consumed energy (limited timing) Total locally produced energy Seasonality input data for scaling Optional: weather data	Year-long energy consumption and production characteristics
Build a forecast of community-level Imported Energy	Build and train a model estimating the imported energy metric during the year on a community level	Total consumed energy Total locally produced energy (DER) Seasonality input data for scaling Optional: weather data	Imported Energy Forecast model (medium to long term)
Temporal Energy Usage profiling	Gain further understanding on the composition of the customer portfolio by analysing and identifying common patterns on the amount and temporal use of the energy, which can be used to identify similar peers	Customer imported energy	Clusters of customers Clusters characterization Average characteristics of clusters (centroids)
Elasticity (flexibility) profiling at end user level	Extrapolate the available flexibility from the different time frames	Imported energy End user demand profiles DER production Weather and ambient data	Available flexibility profiles – at end user level
Elasticity (flexibility) profiling at end user level	Extrapolate the available flexibility from the different time frames	Large scale community controllable consumption (e.g. EV chargers, public lighting) demand profile	Available flexibility profiles – at larger scale community sized consumer level

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Elasticity Analysis	Analyze the maximization of own consumption at community level, respecting the limits in the two elasticity profilings above	Flexibility profiles DER production profile Demand profile	Own consumption maximization indicators
Energy poverty intrinsic alleviation capability	Estimate community-level energy poverty alleviation potential through unused savings. "Blind" optimization of a single consumer does not necessarily yield community level maximum savings and minimization of exposure to expensive energy imports to the community.	Large-scale consumption at community level (proxied through public lighting data) Own consumption at end user level Community level own DER production Community level available flexibilty	Unused potential of local consumption for energy savings (i.e. avoided import outside community)
Business case evaluation	Based on technical analysis perform a sensitivity analysis to deliver a business cases	Elasticity analysis outputs Energy poverty analysis outputs Pricing assumptions (scenario analysis)	Business case data for the management of local community
Outlier filtering	Anomaly/outlier detection in the input series data	All time series	Unexpected demand/Outliers with values outside normal range

Energy applications

The energy applications that will be used to develop DC21 are introduced in the next table.

Table 88: Energy applications to be used within DC21

Energy app name	Components	Input data assets (IDA)	Output data assets (ODA)

Portfolio Analytics and Management Application	The portfolio analytics in this context is used at community level. As the flexibility market in Croatia is still emerging we focus on business case evaluation in the context of Demo Case 21, providing all technical inputs. Portfolio Pattern Forecasting Engine will be used to deliver accurate demand forecasts based on consumption patterns and seasonality data Customer Segmentation Engine will be used to obtain customer segments based on various criteria	HR_KRK_10 - HR_KRK_14 – direct usage HR_KRK_7-9 – local large scale consumption HR_KRK_1 to 5 – local energy PV production Further data assets to estimate year-long seasonal patterns	Estimated demand profile per customer Elasticity profile per customer Elasticity profiles clusters
Personalized Energy Analytics Application	Personalized Energy Analytics Engine component will be used to study consumption patterns and obtain targeted suggestions for improving energy performance	Same as the above	Targeted suggestions to improve own consumption (at individual level) Aggregate suggestions at community level
Self-Consumption Optimization	Self consumption optimization component will be used to maximize own consumption at aggregate community level	Same as the above	Community level own consumption optimization
Flexibility Analytics and Consumer-Centric DR Optimization Application	Estimation of available flexibility margins at consumer level	Same as the above	Flexibility margins as key inputs for business case analysis

As already stated in the Deliverable D8.1, the above applications are expected to be used in the implementation of SYNERGY within the Demo Case 21, however we foresee that the further phases of SYNERGY usage in Krk will also expand towards the energy apps targeting the network management and real-time building certification.

Workflow

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The general workflow of DC21 is illustrated in the following diagram.

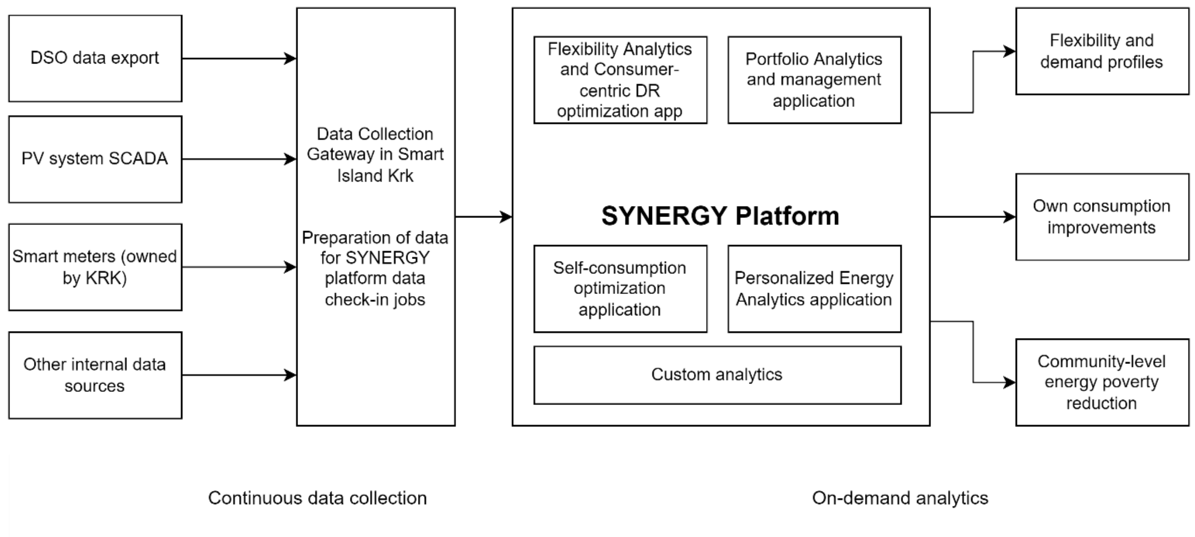

Figure 49:DC 21 workflow diagram

The workflow is relatively simple. The relatively long and complicated initial phase contains the unlock of the existing data siloes. Once this is achieved, and at the time of this deliverable writing this is only achieved partially, then the data is being constantly gathered. The actual analytics is triggered manually.

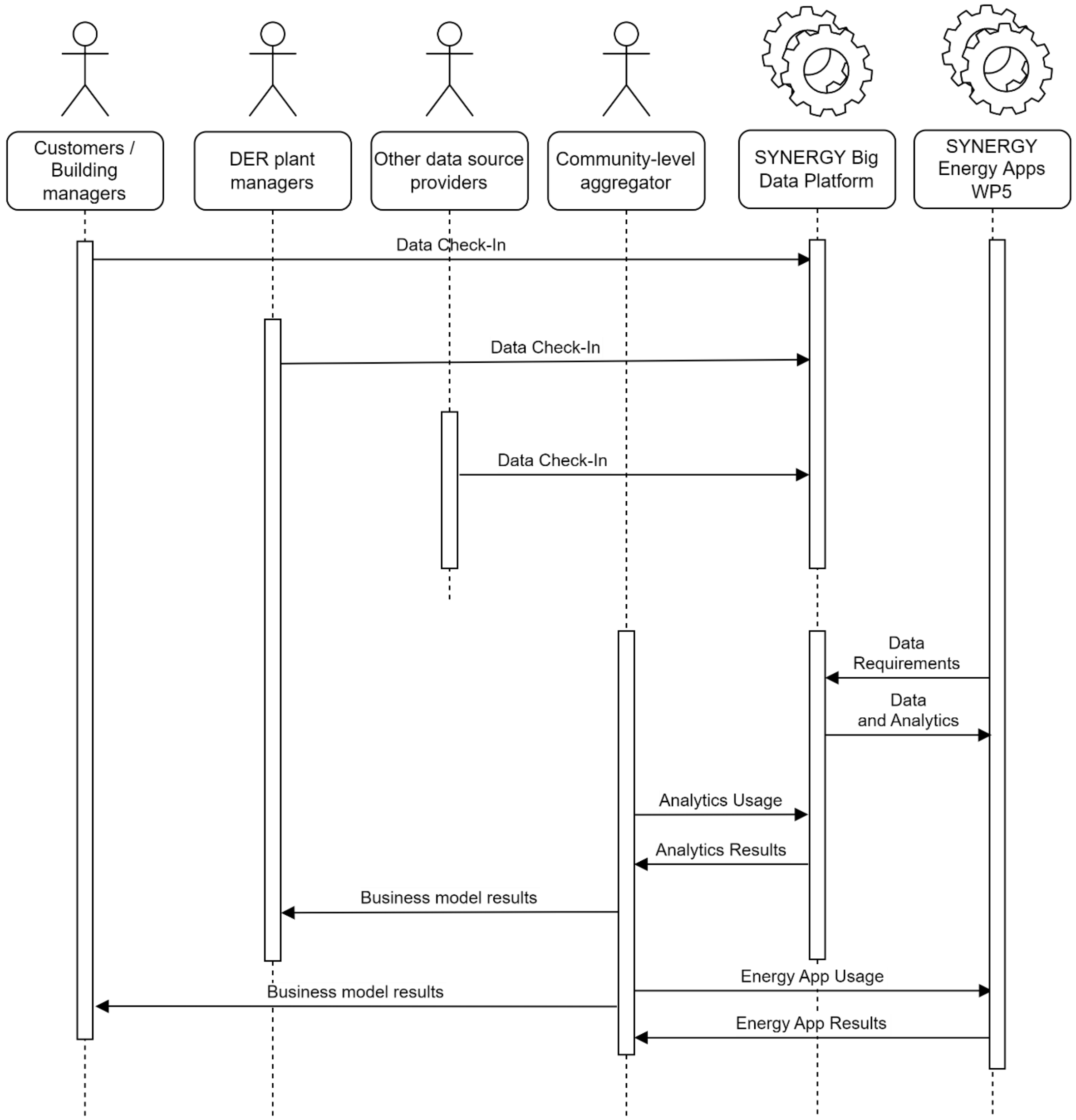

Figure 50:DC21 sequence diagram

The above figure depicts the sequence diagram of Demo Case 21. Again, the Krk partners play a multifaceted role here, so they are at the same time customers, building and DER managers/owners and prospective aggregators. It is expected that a part of the analytics relevant to this demo case happens outside the energy apps (i.e. directly on the SYNERGY platform) and that the prospective aggregator is a community-level intermediary providing final modeling results to initial data providing actors. The aggregator is the entity doing the triggering of the analytics, indicated in the above workflow.

5.5.1.2 Impact KPIs

This demo case impact is principally measured in the KPIs related to change of energy consumption from the local sources and the utilization of available flexibility as well as curtailment of local renewables. These indicators are direct inputs to a business case evaluation seen from the district (i.e. community) viewpoint is calculated and this is the principal outcome of this demo case.

This is the indicative list of indicators expected to be used in this demo case.

KPI ID	KPI name	KPI impact category	KPI aspect
1	Peak load demand reduction	Energy	Network observability, Network Availability, Power quality (voltage quality, continuity of supply)
25	Self-consumption ratio (for the consumer/aggregator)	Energy	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency
26	Cost savings for consumers and other stakeholders	Economic	Cost Savings
30	Energy Savings (storage driven/ RES driven)	Energy	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency
32	Building's total renewable generation	Energy	RES Integration, Energy Savings, Energy Performance
34	Flexibility for the grid and storage for the building	Energy	Energy Efficiency, Retailer Portfolio efficiency, Energy Performance
45	Actual Flexibility Availability	Energy	Flexibility, DER activation
54	Payback Period	Economic	
55	Return on investment	Economic	

The payback period and ROI are the result of the final business case analysis as described in the following section.

5.5.1.3 Preliminary evaluation plan

The principal issue in DC21 is to gather a representative data set in winter and summer months to properly gather the seasonality issues: the problem for any setup to increase own consumption of the community is the large difference in summer demand compared to winter demand, and on the other

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side, the non-availability of flexibility resources in winter which may require purchasing comparatively expensive energy from firm sources instead of exploiting local renewables.

Within the analytics, the calculation of the performance is derived from a limited data set and extrapolated using a secondary dataset that covers the seasonality aspect. The first demo run in winter scales the data from winter to summer levels. Once the data from the second demo run is available, the modeling assumptions are updated and then analytics is run again.

For this reason, the input data assets may seem, at first glance, somewhat redundant. However, these are actually divided in four principal classes: consumption at consumer level, production at individual DER level, consumption proxy data at community scale (e.g. public illumination) and seasonality proxy data (at community scale). Community scale consumption is also an important source of flexibility - these are owned, operated and financed at community level.

The plan is to utilize the seasonality proxy data gathered in static fashion (historical) together with actively collected and more finely grained data from the first winter demo run to run a preliminary round of analysis. This will provide the indicative results and first-round comparisons with “business as usual”, i.e. “do nothing” scenario. Between the first and second demo run, the first business modeling round will also be prepared according to the cost-benefit analysis framework by the EU JRC.

The second demo run and the constant data collection between the two demo runs will provide updates to modeling assumptions together with an updated seasonality proxy dataset. This allows correcting and tuning of the modeling assumptions.

In other words – the first demo run will use historical data to extrapolate the seasonality effect, and the second demo run will update the validity of the assumptions using newly collected data in the summer months. After the second demo run, the analytics results and business models are going to be finalized by using the updated results of the second demo run.

6 Conclusions

T8.3's primary objective is to create a global evaluation framework for SYNERGY and facilitate the cost benefit calculation and validation of SYNERGY innovative solutions, as they are offered to different partners, revealing the added value that data sharing, analytics and energy applications, as envisioned by SYNERGY, can bring. Particularly this document, aims to define methods and processes to calculate the anticipated added value of the project both from the energy applications and demo cases perspective and from the data orientation perspective.

Moving towards more technical details, a total number of **54 KPIs** were identified. The details of the KPIs are presented in Annex A. 43 KPIs fall into in the energy impact category, 9 fall into the economic, and finally 2 KPIs fall into the environmental category. A KPI calculation methodology is also described, following processes also identified in other evaluation methodologies in other EU projects and the literature. Apart from the SYNERGY KPIS, a list of Technical KPIs has also been defined introducing a set of Quantitative Technical Evaluation KPIs, Data Asset Quality Evaluation KPIs and User Experience/Acceptance Evaluation KPIs.

Finally, appropriate **demo validation scenarios** have been constructed for all demo cases, providing the stepping stone upon which demo runs will be evaluated. For all the demo cases, the involved stakeholders have been identified, the interacting data analytics and energy applications offered through the SYNEGY platform have been identified and descriptive workflows, along with sequence diagrams and flowcharts showing the steps towards a successful evaluation plan have been also described.

This deliverable opens the path towards a Holistic Performance Evaluation, Impact Assessment and Cost-Benefit Analysis, which will be performed within the deliverable D8.5 'SYNERGY Holistic Performance Evaluation, Impact Assessment and Cost-Benefit Analysis v1' , to be published during M33 of the project, following the end of the first demo run and will be further elaborated and improved, with deliverable D8.6, 'SYNERGY Holistic Performance Evaluation, Impact Assessment and Cost-Benefit Analysis v2' , following the end of the second demo run on M42 of the project.

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ANNEXES

I. SYNERGY KPIs

KPI information	
KPI ID	KPI_1
KPI name	Peak load demand reduction
Impact Category and aspect	Energy, Network observability, Network Availability, Power quality (voltage quality, continuity of supply)
Description	This KPI measures the reduction in the daily peak demand of a consumer after introducing different demand management procedures, as those proposed by BL-EPOM and DLEPOM
Formula	$Peak\ load\ reduction = \frac{Daily\ peak\ load\ (real, kW) - \ Daily\ peak\ load\ (reference, kW)}{Daily\ peak\ load\ (reference, kW)} * 100$
Unit of measurement	%
Related UCs	UC7.5 and UC7.6
Related demo cases	DC-6, DC14, DC15 and DC-21s
Related energy apps	BL-EPOM and DL-EPOM

KPI information	
KPI ID	KPI_2
KPI name	Frequency of congestions
Impact Category and aspect	Energy, network quality

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

Description	This KPI measures the frequency of congestions identified during power flow calculations. Congestions shall be of two types: Line over-loadings and violations of voltage limits. Line overloading is evaluated as the amount by which the real power flow exceeds the maximum power flow limit for the line i.e. the line rating. Voltage violation occurs when the voltage calculated at a bus is above or below the acceptable limits. According to EN 50160 standard, a tolerance of +/- 10% of the nominal voltage is permissible. The indicator shall measure the mean and/or the average number of congestions during a period of analysis (e.g. a year, a set of characteristic days, or a day).
Formula	$$\mathrm{FrequencyOfCongestions_{mean}} = \sum_{t}^{T} \mathrm{number\ of\ congestions}/\mathrm{N}$$ $$\mathrm{FrequencyOfCongestions_{sum}} = \sum_{t}^{T} \mathrm{number\ of\ congestions}$$ T: examined period N: number of tests/ scenarios
Unit of measurement	-
Related UCs	UC5.1, UC5.3
Related demo cases	DC 1, DC 2, DC 3, DC 10, DC 12, DC 13, DC 14
Related energy apps	Infrastructure Sizing and Grid Planning Application Flexibility based Network Management and DSO-TSO common operational scheduling Application

KPI information	
KPI ID	KPI_3
KPI name	Size of congestion

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

Impact Category and aspect	Energy, network quality
Description	This KPI measures the size of congestions identified during power flow calculations. Congestions shall be of two types: Line over-loadings and violations of voltage limits. Line overloading is evaluated as the amount by which the real power flow exceeds the maximum power flow limit for the line i.e. the line rating. Voltage violation occurs when the voltage calculated at a bus is above or below the acceptable limits. According to EN 50160 standard, a tolerance of +/- 10% of the nominal voltage is permissible. The indicator shall measure the size of the congestion beyond the acceptable limits.
Formula	$\mathrm{SizeOfCongestion_{current}} = \frac{\mathrm{line\ loading_{calculated}} - \mathrm{line\ loading_{rated}}}{\mathrm{line\ loading_{rated}}} * 100$ $\mathrm{SizeOfCongestion_{voltage}} = \begin{cases} \frac{V_{calculated} - V_{max}}{V_{max}} * 100 & \text{if } V_{calculated} > V_{max} \\ \frac{V_{calculated} - V_{min}}{V_{min}} * 100 & V_{calculated} < V_{min} \end{cases}$ $V_{calculated}$: voltage level calculated within the power flow V_{max}, V_{min}: voltage upper and lower limits for acceptable operation
Unit of measurement	%
Related UCs	UC5.1, UC5.3
Related demo cases	DC 1, DC 2, DC 3, DC 10, DC 12, DC 13, DC 14
Related energy apps	Infrastructure Sizing and Grid Planning Application Flexibility based Network Management and DSO-TSO common operational scheduling Application

KPI information	
KPI ID	*KPI_4*
KPI name	*Volume of flexibility requested*

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Impact Category and aspect	*Energy, Flexibility, DER activation*
Description	This KPI evaluates the total amount of flexibility requested from the network operator under the examined period. The period could be a season, when the operator could decide and contract flexible capacity rather than proceeding with new investments or it could be a day, measuring the flexibility requested for the intraday or day ahead market. The requested flexibility shall be utilized for ancillary services (congestion management or balancing).
Formula	$$VolumeOfFlexibilityRequested = \sum_{t}^{T} P\_flexibility_t$$ T: examined period $P\_flexibility_t$: the amount of power requested from flexible resources during time t (kW)
Unit of measurement	kW
Related UCs	UC5.1, UC5.3
Related demo cases	DC 1, DC 2, DC 3, DC 10, DC 12, DC 13, DC 14
Related energy apps	Infrastructure Sizing and Grid Planning Application Flexibility based Network Management and DSO-TSO common operational scheduling Application

KPI information	
KPI ID	*KPI_5*
KPI name	*Congestion alleviation*
Impact Category and aspect	*Energy, network quality*
Description	This KPI evaluates the reduction of congestion events identified in the network upon the implementation of SYNERGY R&I solutions (such as utilization of flexibility, DER or network reinforcement)

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Formula	$$CongestionAlleviation = 1 - \frac{FrequencyOfCongestions_{BaU}}{FrequencyOfCongestions_{R\&I}} * 100$$ BaU: business as usual operation $R\&I$: operation upon the implementation of SYNERGY R&I solutions (such as utilization of flexibility, DER or network reinforcement)
Unit of measurement	%
Related UCs	UC5.1, UC5.3
Related demo cases	DC 1, DC 2, DC 3, DC 10, DC 12, DC 13, DC 14
Related energy apps	Infrastructure Sizing and Grid Planning Application Flexibility based Network Management and DSO-TSO common operational scheduling Application

KPI information	
KPI ID	*KPI_6*
KPI name	*Reduction in VRES curtailment*
Impact Category and aspect	*Energy, RES integration*
Description	This KPI evaluates the reduction of energy curtailment from Renewable Energy Sources (RES) that is not injected to the grid (even though it is available) due to operational limits of the grid, such as voltage violations or congestions. Reduction of curtailment shall occur upon the implementation of SYNERGY R&I solutions (such as utilization of flexibility, DSO-TSO coordination).
Formula	$$ReductionCurtailment_{RES} = 1 - \frac{RES\_Curtailment_{BaU}}{RES\_Curtailment_{R\&I}} * 100$$ BaU: business as usual operation

	$R\&I$: operation upon the implementation of SYNERGY R&I solutions (such as utilization of flexibility, DER or network reinforcement)
Unit of measurement	%
Related UCs	UC5.3, UC5.4
Related demo cases	DC 1, DC 2, DC 3, DC 10, DC 12, DC 13, DC 14
Related energy apps	Flexibility based Network Management and DSO-TSO common operational scheduling Application

KPI information	
KPI ID	*KPI_7*
KPI name	*DER hosting capacity increase*
Impact Category and aspects	*Energy, RES integration*
Description	Hosting capacity is the amount of DERs that the electric distribution system can reliably accommodate without significant grid upgrades. This KPI evaluates the increase on DER hosting capacity upon the implementation of SYNERGY R&I solutions (such as utilization of flexibility, DSO-TSO coordination).
Formula	$$HostingCapacity_{RES} = 1 - \frac{RES\_HostingCapacity_{BaU}}{RES\_HostingCapacity_{R\&I}} * 100$$ BaU: business as usual operation $R\&I$: operation upon the implementation of SYNERGY R&I solutions (such as utilization of flexibility, DER or network reinforcement)
Unit of measurement	%
Related UCs	UC5.1, UC5.2
Related demo cases	DC 3, DC 10, DC 12, DC 13, DC 14

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Related energy apps	Infrastructure Sizing and Grid Planning Application

KPI information	
KPI ID	*KPI_8*
KPI name	*Active power deviation from flexible units*
Impact Category and aspects	*Energy, Flexibility, DER activation*
Description	This KPI evaluates the divergence of the active power flows of each flexible unit from their characteristic average values provided by the portfolio analytics. The aim is to calculate aggregated active power offered by flexible units to quantify the capacity needs of the operators and inform flexibility portfolio managers.
Formula	$$ActivePowerDeviation_{flex} = \sum_{t}^{T} ActivePower_{flex,t} - \overline{ActivePower_{flex,t}}$$ T: examined period $ActivePower_{flex,t}$: active power of flexible units during time t $\overline{ActivePower_{flex,t}}$: average or expected value of flexible units as given by portfolio analytics during time t
Unit of measurement	kW
Related UCs	UC5.1, UC5.3
Related demo cases	DC 1, DC 2, DC 3, DC 10, DC 12, DC 13, DC 14
Related energy apps	Infrastructure Sizing and Grid Planning Application Flexibility based Network Management and DSO-TSO common operational scheduling Application

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KPI information	
KPI ID	*KPI_9*
KPI name	*Activated flexibility compared to available flexibility*
Impact Category and aspect	*Energy, Flexibility, DER activation*
Description	This KPI evaluates the activated flexibility provided by flexible resources and used from the operators, compared to the total available flexibility as given by the flexible portfolio managers. This indicator shall inform operators about the remaining flexibility potential not yet utilized, but is available to be used for network services such as congestion management and balancing.
Formula	$$RemainingFlexibility_t = \frac{ActivatedFlexibility_t}{AvailableFlexibility_t}$$ $ActivatedFlexibility$: The amount of power (or energy) activated from flexible resources at time t $AvailableFlexibility$: The amount of power (or energy) available for potential activation from flexible resources at time t
Unit of measurement	%
Related UCs	UC5.1, UC5.2, UC5.3, UC5.4
Related demo cases	DC 1, DC 2, DC 3, DC 10, DC 12, DC 13, DC 14
Related energy apps	Infrastructure Sizing and Grid Planning Application Flexibility based Network Management and DSO-TSO common operational scheduling Application

KPI information	
KPI ID	*KPI_10*
KPI name	*Frequency of flexibility requests for ancillary services*
Impact Category and aspect	*Energy, Flexibility, DER activation*

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Description	This KPI measures the total number of flexibility requests from the network operator towards the flexibility portfolio manager. The requested flexibility shall be utilized for ancillary services (congestion management or balancing).
Formula	$$TotalFlexibilityRequests = \sum_{t}^{T} N\_flexibility\_requests_t$$ T: examined period $N_{flexibility\_requested_t}$: number of flexibility requests at time t
Unit of measurement	-
Related UCs	UC5.3, UC5.4
Related demo cases	DC 1, DC 2, DC 3, DC 10, DC 12, DC 13, DC 14
Related energy apps	Flexibility based Network Management and DSO-TSO common operational scheduling Application

KPI information	
KPI ID	*KPI_11*
KPI name	Cost of R&I solution VS grid alternative solution
Impact Category and aspect	*Economic, Cost Savings,* O&M Costs savings
Description	This KPI evaluates the potential cost savings from deferred grid investments for the network operator, when they decide to proceed with contracting and activating flexibility to manage congestions.
Formula	$$CostVariation = \frac{CAPEX_{BaU} - CAPEX_{R\&I}}{CAPEX_{BaU}} * 100$$ $CAPEX_{BaU}$: Cost of new reinforcements $CAPEX_{R\&I}$: Cost of flexibility

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	BaU: business as usual operation $R\&I$: operation upon the implementation of SYNERGY R&I solutions (such as utilization of flexibility, DER or network reinforcement)
Unit of measurement	%
Related UCs	UC5.1, UC5.2
Related demo cases	DC 3, DC 10, DC 12, DC 13, DC 14
Related energy apps	Infrastructure Sizing and Grid Planning Application

KPI information	
KPI ID	*KPI_12*
KPI name	*PV performance ratio*
Impact Category and aspect	Energy, Retailer Portfolio efficiency, Energy Efficiency, Energy Savings, RES Integrations
Description	PV Performance Ratio (PR): It provides an indication of the performance in real conditions of the PV plants. In the IEC 61724-1 standard, the Performance Ratio (PR) is defined as the ratio between the Final Energy Yield and the Reference Yield. It is the equivalent of the ratio between the effective energy produced (AC), which could be injected to the grid, and the energy available from the sun. It accounts for all the losses in the PV system, such as: efficiency loss of modules and converters, resistive losses in cables, temperature, and irradiance effects, far and near shadowing, soiling, components outages, etc. The main aim sought with this KPI is to assess how the operation strategies of a PV asset and the energy yield could be improved when several key indexes are monitored, thus maximising the energy generation. The data that will be used to calculate this KPI will be: climatic information coming from the PV asset which is registered in a database and that is collected through the monitoring system locally installed. Different internal documents will be used to evaluate how the PR changes along the different seasons of the year, and how it evolves during the demo case.

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Formula	$$PR = \frac{E_{out}}{P_0} \Big/ \frac{H}{G_{ref}}$$ Being E_{out} the final energy yield equals the output energy from the system to the network in AC weighted by the peak power of the installation in DC (P_0); and that the reference yield is the total irradiation in the plane of array (H) divided by the reference irradiance (G_{ref} = 1000 W/m^2).
Unit of measurement	%
Related UCs	UC5.5 , UC5.6
Related demo cases	DC7
Related energy apps	Performance monitoring and predictive maintenance application

KPI information	
KPI ID	*KPI_13*
KPI name	*Inverter efficiency*
Impact Category and aspect	Energy, Retailer Portfolio efficiency, Energy Efficiency, Energy Savings, RES Integrations
Description	The inverter efficiency refers to how much dc power will be converted to ac power, as some of power will be lost during this transition.
Formula	$$\eta = \frac{P_{AC}}{P_{DC}}$$
Unit of measurement	%
Related UCs	UC5.5,UC5.6
Related demo cases	DC7
Related energy apps	Performance monitoring and predictive maintenance application

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

KPI information	
KPI ID	*KPI_14*
KPI name	Distribution Equipment Maintenance Cost
Impact Category and aspect	Economic, Cost Savings, O&M Costs savings
Description	The cost of the activities related to equipment maintenance.
Formula	$$DEMC = \frac{\overline{EMC_{R\&I}}}{\overline{EMC_{BaU}}}$$ $EMC_{R\&I}$: Equipment maintenance cost after predictive maintenance strategies are in place (for assets of a particular type) EMC_{BaU}: Equipment maintenance cost before application of predictive maintenance strategies (for assets of a particular type)
Unit of measurement	€ / reporting period
Related UCs	UC5.5, UC5.6 and UC5.7
Related demo cases	DC 3
Related energy apps	Asset management optimization application

KPI information	
KPI ID	*KPI_15*
KPI name	Customers Experiencing Multiple Interruptions
Impact Category and aspect	Energy, Network Availability, Network Quality
Description	Fraction or percentage of the customers experiencing more than N interruptions.

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Formula	$$\sum_{c} \begin{cases} (n_c < N) \mid (t_c \neq T) = 0 \\ (n_c \geq N) \wedge (t_c = T) = 1 \end{cases}$$ n_c: Number of interruptions by customer c. N: Total number of interruptions to consider. t_c: Period of customer c. T: Predefined period.
Unit of measurement	Percentage %
Related UCs	UC5.5 and UC5.7
Related demo cases	DC3
Related energy apps	Asset management optimization application

KPI information	
KPI ID	*KPI_16*
KPI name	*Effectiveness of the asset health estimation*
Impact Category and aspect	Energy, Network Availability, Network Quality
Description	Calculate the effectiveness of the asset health estimation during a period of time.
Formula	$$EAHE = \frac{TP}{(TP + FP)}$$ TP: True positive predictions FP: False positive predictions
Unit of measurement	%

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Related UCs	UC_5_7 Enhanced monitoring of status and health (including VR navigation) of network components
Related demo cases	DC3
Related energy apps	Asset Management Optimization Application

KPI information	
KPI ID	KPI_17a
KPI name	Percentage change of energy consumption for the consumer
Impact Category and aspect	Energy, Energy Savings, Energy Efficiency, Retailer Portfolio efficiency
Description	Comparison of the energy consumption of a single consumer over specific time periods (e.g. current vs previous week, current month vs same month previous year, etc.)
Formula	$\Delta E_c = \frac{\sum_{T1} E_c}{\sum_{T0} E_c}$ T0: base time period of comparison T1: target time period of comparison E_c: energy consumption readings for customer c
Unit of measurement	%
Related UCs	UC6.3, UC6.7
Related demo cases	DC 21
Related energy apps	Portfolio Analytics and Management Application Personalized Energy Analytics

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KPI information	
KPI ID	*KPI_17b*
KPI name	*Percentage change of total energy consumption (for portfolio)*
Impact Category and aspect	Energy, Energy Savings, Energy Efficiency, Retailer Portfolio efficiency
Description	Comparison of the energy consumption of a complete retailer's portfolio of customers over specific time periods (e.g. current vs previous week, current month vs same month previous year, etc)
Formula	$\Delta E_p = \frac{\sum_{T1}\sum_{P} E_c}{\sum_{T0}\sum_{P} E_c}$ T0: base time period of comparison T1: target time period of comparison E_c: energy consumption readings for customer c P: portfolio of customers
Unit of measurement	%
Related UCs	UC_6_3, UC_6_7
Related demo cases	DC 21
Related energy apps	Portfolio Analytics and Management Application Personalized Energy Analytics

KPI information	
KPI ID	*KPI_18*
KPI name	Generation Forecasting Accuracy

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 872734.

Impact Category and aspect	Energy, Generation/Demand forecasting
Description	This KPI calculates the accuracy of the forecast of generation (modelled) compared to actual generation potential during a period of analysis (e.g. a year, a set of characteristic days etc,).
Formula	$GenerationForecastingAccuracy = \left(\frac{\sum_{t\in T}\lvert Gen_{t,Actual} - Gen_{t,Forecast}\rvert}{\sum_{t\in T} Gen_{t,Actual}}\right) \times 100$ $Gen_{t,Actual}$ is the actual flexibility (potential) during the metering period. $Gen_{t,Forecast}$ is the forecasted flexibility potential during the metering period. T is the total period of observation.
Unit of measurement	%
Related UCs	UC6.4 ,UC7.5 and UC7.6
Related demo cases	DC5-DC6-DC12-DC14-DC15-DC21
Related energy apps	Flexibility Analytics and Consumer-Centric DR Optimization Application BL-EPOL and DL-EPOM

KPI information	
KPI ID	*KPI_19*
KPI name	Flexibility Forecasting Accuracy
Impact Category and aspect	Flexibility, DER activation
Description	This KPI calculates the accuracy of the forecast of flexibility (modelled) compared to actual flexibility potential during a period of analysis (e.g. a year, a set of characteristic days etc,).
Formula	$FlexibilityForecastingAccuracy = \left(\frac{\sum_{t\in T}\lvert Flex_{t,Actual} - Flex_{t,Forecast}\rvert}{\sum_{t\in T} Flex_{t,Actual}}\right) \times 100$

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	$Flex_{t,Actual}$ is the actual flexibility (potential) during the metering period. $Flex_{t,Forecast}$ is the forecasted flexibility potential during the metering period. T is the total period of observation.
Unit of measurement	%
Related UCs	UC6.4
Related demo cases	DC5-DC12-DC15-DC21
Related energy apps	Flexibility Analytics and Consumer-Centric DR Optimization Application

KPI information	
KPI ID	KPI_20
KPI name	Demand forecasting accuracy
Impact Category and aspect	Energy Savings, Energy Efficiency, Retailer Portfolio efficiency, Generation/Demand forecasting
Description	The indicator will measure the Mean Absolute Percentage Error (MAPE) between actual and forecasted demand.
Formula	$\mathrm{MAPE} = \frac{\sum_{t=1}^{N} \left\lvert \frac{E_t}{D_t} \right\rvert}{N}$ E_t: forecast error at period t ($E_t = D_t - F_t$) D_t: actual value of demand at period t F_t: forecasted demand at period t N: number of available data points of the demand time series
Unit of measurement	%
Related UCs	UC6.1

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Related demo cases	DC 21
Related energy apps	Portfolio Analytics and Management Application

KPI information	
KPI ID	KPI_21
KPI name	Building energy consumption forecasting accuracy
Description	This indicator shows the ability of the application to reduce the gap between predicted and actual energy consumption of individual buildings and also in the studies city district area
Formula	$R^2 = \sum (y\hat{}i - y)^2 / \sum (y_i - y)^2$ $RMSE = S\ (1/n \sum (y_i - y\hat{}_i)^2)$ $NRMSE = RMSE/\ (y_{max} - y_{min})$ Where, NRMSE - Normalized root-mean-square error, R^2 - coefficient of determination, y_i is the observation, y is its mean, and $y\hat{}_i$ is predicted value, y_{max} and y_{min} are the maximum and minimum values of y, respectively
Unit of measurement	RMSE (mW)
Related UCs	UC7.1, UC7.2, UC7.3
Related demo cases	DC 17, 18, 19
Related energy apps	Advanced Renovation Support App The Urban Energy Monitoring and Planning Support App

KPI information

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KPI ID	*KPI_22*
KPI name	GHG Emissions reduction
Impact Category and aspect	Environmental, Emissions
Description	Increasing the integration of DER and the energy usage awareness of end-users should promote the transition towards a greener energy mix and a reduction of energy demand (and therefore of its associated equivalent emissions). Comparison of the GHG emissions can be applied to single consumers, facilities or consumers portfolio over specific time periods (e.g. current vs previous week, current month vs same month previous year, etc.)
Formula	$\Delta GHG = \frac{\sum_{T1} GHG}{\sum_{T0} GHG}$ $GHG = \sum_{h} CEC_h L_h$ T0: base time period of comparison T1: target time period of comparison CEC_h: the Carbon Emission Coefficient during each time interval h of the period under study; it must reflect the carbon emissions of the respective generation facilities and will be significantly lower when RES generation has a greater share in the total production than fossil fuel-based generation (tn CO_2/kWh) $L_h = \sum_{n \in N} l_n^h$: the total load across all users $n \in N$ during each time interval h of the period under study (kWh) H: the set of time intervals of the period under study N: the set of customers under study
Unit of measurement	%
Related UCs	UC6.3, UC6.7
Related demo cases	DC 21
Related energy apps	Portfolio Analytics and Management Application

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	Personalized Energy Analytics

KPI information	
KPI ID	*KPI_23*
KPI name	*Building CO_2 emissions*
Impact Category and aspect	Environmental, Emissions
Description	This KPI calculates the CO_2 emissions of the building for a specific timestamp and upon request from the user. The CO_2 emissions are calculated as the total energy demand of the building for the time period of reference times the CO_2 emissions factor ($kgCO_2/kWh$) of the country where the building is located
Formula	$CO_{2emissions} = \sum_{starttime}^{endtime} (energy\ demand\ meter\ readings) \times CO_{2factor}$
Unit of measurement	$kgCO_2$
Related UCs	UC7.7
Related demo cases	DC20
Related energy apps	eDECs

KPI information	
KPI ID	KPI_24
KPI name	Thermal comfort of occupants
Impact Category and aspect	Local Energy Communities efficiency

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Description	This KPIs measures the hours the temperature is out of the limits per month when using energy apps
Formula	$\text{Thermal comfort of occupants} = \sum \text{hours with average temperature out of limits along a month}$
Unit of measurement	h/month
Related UCs	UC7.5 and UC7.6
Related demo cases	DC-6, DC14, DC15 and DC-21
Related energy apps	DL-EPOM and BE-EPOM

KPI information	
KPI ID	KPI_25
KPI name	Self-consumption ratio (for the consumer/aggregator)
Impact Category and aspect	Facility Management Efficiency, Self-Consumption Optimization & Predictive Maintenance
Description	This KPI measures the energy consumed by a customer that has been generated by the consumer in its facilities
Formula	$\text{Self consumption} = \frac{\text{Daily energy generated by the consumer} - \text{Daily energy consumed by the consumer}}{\text{Daily energy nergy consumed by the consumer}} * 100$
Unit of measurement	%
Related UCs	UC7.5 and UC7.6
Related demo cases	DC-6, DC14, DC15 and DC-21
Related energy apps	BL-EPOM and DL-EPOM

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KPI information	
KPI ID	*KPI_26*
KPI name	*Cost savings for* consumers and other stakeholders
Impact Category and aspect	*Economic, Cost Savings*
Description	This KPI measures the cost savings after the use of the different tools proposed with SYNERGY regarding building and district energy performance optimization
Formula	$CS = Total\ monthly\ costs\ (R\&I) - Total\ monthly\ costs\ (BaU)$
Unit of measurement	€
Related UCs	UC7.5 and UC7.6
Related demo cases	DC-6, DC14, DC15 and DC-21
Related energy apps	BL-EPOM and DL-EPOM

KPI information	
KPI ID	*KPI_27*
KPI name	*Cost of purchasing energy*
Impact Category and aspect	*Economic, Cost Savings*
Description	*This KPI measures the cost of the purchasing energy by the customer along time*
Formula	$COPE = \frac{NPV\ of\ total\ costs\ ofnergy\ purchased\ from\ the\ grid\ over\ lifetime}{Total\ electric\ energy\ purchased\ from\ the\ grid\ \ over\ lifetime}$
Unit of measurement	*€/kWh*
Related UCs	*UC7.5 and UC7.6*

Related demo cases	DC-6, DC14, DC15 and DC-21
Related energy apps	*BL-EPOL and DL-EPOM*

KPI information	
KPI ID	*KPI_28*
KPI name	*Levelized cost of energy*
Impact Category and aspect	*Economic, Cost Savings*
Description	*This KPI measures the cost of the energy consumed by the customer along time*
Formula	$LCOE = \frac{NPV\ of\ total\ costs\ over\ lifetime}{Total\ electric\ energy\ consumed\ \ over\ lifetime}$
Unit of measurement	*€/kWh*
Related UCs	*UC7.5 and UC7.6*
Related demo cases	*DC7,* DC-6, DC14, DC15 and DC-21
Related energy apps	*BL-EPOL and DL-EPOM*

KPI information	
KPI ID	*KPI_29*
KPI name	Costs savings due to renovation actions
Impact Category and aspect	*Economic, Cost Savings*
Description	This indicator shows the ability of the application to reduce the costs invested to select the required renovation actions

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Formula	$C = \Delta T \times C_h + C_t$ where C - cost, ΔT - time saving (see KPI_41 'time saving to select the required renovation actions'), C_h - hour cost of work, C_t - cost of used tools
Unit of measurement	Eur
Related UCs	UC_7_1, UC_7_2,
Related demo cases	Demo Cases 19
Related energy apps	Advanced Renovation Support App

KPI information	
KPI ID	*KPI_30*
KPI name	*Energy savings (storage driven, RES driven)*
Impact Category and aspect	*Retailer Portfolio efficiency, Energy Savings, Energy Efficiency*
Description	*This KPI measures the energy saving generated by the use of storage and/or RES*
Formula	$Energy\ Savings = \frac{Daiy\ demand\ (real, kWh) - \ Daiy\ demand\ (reference, kWh)}{Daiy\ demand\ (reference, kWh)} * 100$
Unit of measurement	*%*
Related UCs	*UC7.5 and UC7.6*
Related demo cases	DC-6, DC14, DC15 and DC-21
Related energy apps	*BL-EPOM and DL-EPOM*

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KPI information	
KPI ID	*KPI_31*
KPI name	*Energy rating of the building*
Impact Category and aspect	*Energy, Energy Performance*
Description	This KPI calculates the energy rating of the building for a specific timestamp and upon request from the user. The final rating is calculated as the percentage of the building's actual energy demand for a specific period VS the baseline energy demand resulting from the Elexon's baseline load profiles, CIBSE's reference energy demand values for different buildings, normalised to the weather conditions of the country where the building is located
Formula	$Energy\ Rating = \sum_{starttime}^{endtime}(energy\ demand\ meter\ readings) \Big/ \sum_{starttime}^{endtime}(baseline\ energy\ demand)$
Unit of measurement	% (or A to G scale)
Related UCs	UC_7_7
Related demo cases	DC20
Related energy apps	eDECs

KPI information	
KPI ID	*KPI_32*
KPI name	*Building's total renewable generation*

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Impact Category and aspect	*Energy, Energy Performance*
Description	This KPI calculates the total amount of renewable energy produced in the building for a specific timestamp and upon request from the user as the sum of the measured energy produced for the respective timestamp
Formula	$RE_{generated} = \sum_{starttime}^{endtime}(energy\ generation\ meter\ readings)$
Unit of measurement	kWh
Related UCs	UC_7_7
Related demo cases	DC20
Related energy apps	eDECs

KPI information	
KPI ID	*KPI_33*
KPI name	*Energy savings on site for the building*
Impact Category and aspect	*Energy, Energy Performance*
Description	This KPI calculates the impact factor of the smart readiness indicator related to the energy savings on site for the building of reference upon the user's request. Based on the SRI methodology described in deliverable D7.1, this impact factor is the average of the percentage of impact of the 9 different domains (namely heating, DHW, cooling, controlled ventilation, lighting, dynamic building envelope, electricity electric vehicle charging, monitoring and control) of the assessment on energy savings on site. For each domain, the user specifies the functionality levels of several services within the domain based on the characteristics of the services and respective systems of the building. The functionality level of each service corresponds to an impact rating, which is then divided by the maximum rating of the service. The resulting percentage for each service are then averaged for each domain. Finally, the percentage for each domain is multiplied with a relevance factor (0 or 1) and the domain weighting factor (DWF) which depends on the building's location and the building's type (residential or non-residential) both of which are also specified in the SRI methodology.

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Formula	$Impact_{energysavings} = AVERAGE(\sum_{Heating\ Service\ 1}^{Heating\ Service\ N} Impact_{fl} / \sum_{Heating\ Service\ 1}^{Heating\ Service\ N} Max\ Impact \times RelevanceWF \times DWF; \sum_{DHW\ Service\ 1}^{DHW\ Service\ N} Impact_{fl} / \sum_{DHW\ Service\ 1}^{DHW\ Service\ N} Max\ Impact \times RelevanceWF \times BuildingtypeWF \times LocationWF; \sum_{Cooling\ Service\ 1}^{Cooling\ Service\ N} Impact_{fl} / \sum_{Cooling\ Service\ 1}^{Cooling\ Service\ N} Max\ Impact \times RelevanceWF \times DWF; \sum_{CV\ Service\ 1}^{CV\ Service\ N} Impact_{fl} / \sum_{CV\ Service\ 1}^{CV\ Service\ N} Max\ Impact \times RelevanceWF \times DWF; \sum_{Lighting\ Service\ 1}^{Lighting\ Service\ N} Impact_{fl} / \sum_{Lighting\ Service\ 1}^{Lighting\ Service\ N} Max\ Impact \times RelevanceWF \times DWF; \sum_{electricity\ Service\ 1}^{electricity\ Service\ N} Impact_{fl} / \sum_{electricity\ Service\ 1}^{electricity\ Service\ N} Max\ Impact \times RelevanceWF \times DWF; \sum_{DE\ Service\ 1}^{DE\ Service\ N} Impact_{fl} / \sum_{DE\ Service\ 1}^{DE\ Service\ N} Max\ Impact \times RelevanceWF \times DWF; \sum_{EV\ Service\ 1}^{EV\ Service\ N} Impact_{fl} / \sum_{EV\ Service\ 1}^{EV\ Service\ N} Max\ Impact \times RelevanceWF \times DWF; \sum_{MC\ Service\ 1}^{MC\ Service\ N} Impact_{fl} / \sum_{MC\ Service\ 1}^{MC\ Service\ N} Max\ Impact \times RelevanceWF \times DFW)$
Unit of measurement	%
Related UCs	UC7.8
Related demo cases	DC20
Related energy apps	SRI

KPI information	
KPI ID	*KPI_34*
KPI name	*Flexibility for the grid and storage for the building*
Impact Category and aspect	*Energy, Energy Performance*

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Description	This KPI calculates the impact factor of the smart readiness indicator related to flexibility and storage for the building of reference upon the user's request. Based on the SRI methodology described in deliverable D7.1, this impact factor is the average of the percentage of impact of the 9 different domains (namely heating, DHW, cooling, controlled ventilation, lighting, dynamic building envelope, electricity electric vehicle charging, monitoring and control) of the assessment on flexibility and storage. For each domain, the user specifies the functionality levels of several services within the domain based on the characteristics of the services and respective systems of the building. The functionality level of each service corresponds to an impact rating, which is then divided by the maximum rating of the service. The resulting percentage for each service is then averaged for each domain. Finally, the percentage for each domain is multiplied with a relevance factor (0 or 1) and the domain weighting factor (DWF) which depends on the building's location and the building's type (residential or non-residential) both of which are also specified in the SRI methodology.
Formula	$Impact_{flexibility\ and\ storage} = AVERAGE(\sum_{Heating\ Service\ 1}^{Heating\ Service\ N} Impact_{fl} \Big/ \sum_{Heating\ Service\ 1}^{Heating\ Service\ N} Max\ Impact \times RelevanceWF \times DWF\ ; \sum_{DHW\ Service\ 1}^{DHW\ Service\ N} Impact_{fl} \Big/ \sum_{DHW\ Service\ 1}^{DHW\ Service\ N} Max\ Impact \times RelevanceWF \times DWF\ ; \sum_{Cooling\ Service\ 1}^{Cooling\ Service\ N} Impact_{fl} \Big/ \sum_{Cooling\ Service\ 1}^{Cooling\ Service\ N} Max\ Impact \times RelevanceWF \times DWF; \sum_{CV\ Service\ 1}^{CV\ Service\ N} Impact_{fl} \Big/ \sum_{CV\ Service\ 1}^{CV\ Service\ N} Max\ Impact \times RelevanceWF \times DWF\ ; \sum_{Lighting\ Service\ 1}^{Lighting\ Service\ N} Impact_{fl} \Big/ \sum_{Lighting\ Service\ 1}^{Lighting\ Service\ N} Max\ Impact \times RelevanceWF \times DWF; ; \sum_{electricity\ Service\ 1}^{electricity\ Service\ N} Impact_{fl} \Big/ \sum_{electricity\ Service\ 1}^{electricity\ Service\ N} Max\ Impact \times RelevanceWF \times DWF; \sum_{DE\ Service\ 1}^{DE\ Service\ N} Impact_{fl} \Big/ \sum_{DE\ Service\ 1}^{DE\ Service\ N} Max\ Impact \times RelevanceWF \times DWF; ; \sum_{EV\ Service\ 1}^{EV\ Service\ N} Impact_{fl} \Big/ \sum_{EV\ Service\ 1}^{EV\ Service\ N} Max\ Impact \times RelevanceWF \times BuildingtypeWF \times LocationWF\ ; \sum_{MC\ Service\ 1}^{MC\ Service\ N} Impact_{fl} \Big/ \sum_{MC\ Service\ 1}^{MC\ Service\ N} Max\ Impact \times RelevanceWF \times DWF)$
Unit of measurement	%
Related UCs	UC7.8
Related demo cases	DC20

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Related energy apps	SRI

KPI information	
KPI ID	*KPI_35*
KPI name	*Comfort for the building*
Impact Category and aspect	*Energy, Energy Performance*
Description	This KPI calculates the impact factor of the smart readiness indicator related to the comfort of the building of reference upon the user's request. Based on the SRI methodology described in deliverable D7.1, this impact factor is the average of the percentage of impact of the 9 different domains (namely heating, DHW, cooling, controlled ventilation, lighting, dynamic building envelope, electricity electric vehicle charging, monitoring and control) of the assessment on comfort. For each domain, the user specifies the functionality levels of several services within the domain based on the characteristics of the services and respective systems of the building. The functionality level of each service corresponds to an impact rating, which is then divided by the maximum rating of the service. The resulting percentage for each service is then averaged for each domain. Finally, the percentage for each domain is multiplied with a relevance factor (0 or 1) and the domain weighting factor (DWF) which depends on the building's location and the building's type (residential or non-residential) both of which are also specified in the SRI methodology.
Formula	$Impact_{comfort} = AVERAGE(\sum_{Heating\ Service\ 1}^{Heating\ Service\ N} Impact_{fl} \Big/ \sum_{Heating\ Service\ 1}^{Heating\ Service\ N} Max\ Impact \times RelevanceWF \times DWF\ ;\ \sum_{DHW\ Service\ 1}^{DHW\ Service\ N} Impact_{fl} \Big/ \sum_{DHW\ Service\ 1}^{DHW\ Service\ N} Max\ Impact \times RelevanceWF \times DWF\ ;\ \sum_{Cooling\ Service\ 1}^{Cooling\ Service\ N} Impact_{fl} \Big/ \sum_{Cooling\ Service\ 1}^{Cooling\ Service\ N} Max\ Impact \times RelevanceWF \times DWF;\ \sum_{CV\ Service\ 1}^{CV\ Service\ N} Impact_{fl} \Big/ \sum_{CV\ Service\ 1}^{CV\ Service\ N} Max\ Impact \times RelevanceWF \times DWF\ ;\ \sum_{Lighting\ Service\ 1}^{Lighting\ Service\ N} Impact_{fl} \Big/ \sum_{Lighting\ Service\ 1}^{Lighting\ Service\ N} Max\ Impact \times RelevanceWF \times DWF;\ ;\ \sum_{electricity\ Service\ 1}^{electricity\ Service\ N} Impact_{fl} \Big/ \sum_{electricity\ Service\ 1}^{electricity\ Service\ N} Max\ Impact \times RelevanceWF \times DWF\ ;\ \sum_{DE\ Service\ 1}^{DE\ Service\ N} Impact_{fl} \Big/ \sum_{DE\ Service\ 1}^{DE\ Service\ N} Max\ Impact \times RelevanceWF \times DWF;$

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	$\sum_{EV\ Service\ 1}^{EV\ Service\ N} Impact_{fl} \Big/ \sum_{EV\ Service\ 1}^{EV\ Service\ N} Max\ Impact \times RelevanceWF \times DWF;$ $\sum_{MC\ Service\ 1}^{MC\ Service\ N} Impact_{fl} \Big/ \sum_{MC\ Service\ 1}^{MC\ Service\ N} Max\ Impact \times RelevanceWF \times DWF)$
Unit of measurement	%
Related UCs	UC_7_8
Related demo cases	DC20
Related energy apps	SRI

KPI information	
KPI ID	*KPI_36*
KPI name	*Convenience for the building*
Impact Category and aspect	*Energy, Energy Performance*
Description	This KPI calculates the impact factor of the smart readiness indicator related to the convenience of the building of reference upon the user's request. Based on the SRI methodology described in deliverable D7.1, this impact factor is the average of the percentage of impact of the 9 different domains (namely heating, DHW, cooling, controlled ventilation, lighting, dynamic building envelope, electricity electric vehicle charging, monitoring and control) of the assessment on convenience. For each domain, the user specifies the functionality levels of several services within the domain based on the characteristics of the services and respective systems of the building. The functionality level of each service corresponds to an impact rating, which is then divided by the maximum rating of the service. The resulting percentage for each service is then averaged for each domain. Finally, the percentage for each domain is multiplied with a relevance factor (0 or 1) and the domain weighting factor (DWF) which depends on the building's location and the building's type (residential or non-residential) both of which are also specified in the SRI methodology.
Formula	$Impact_{convenience} =$ $AVERAGE(\sum_{Heating\ Service\ 1}^{Heating\ Service\ N} Impact_{fl} \Big/ \sum_{Heating\ Service\ 1}^{Heating\ Service\ N} Max\ Impact \times$ $RelevanceWF \times DWF; \sum_{DHW\ Service\ 1}^{DHW\ Service\ N} Impact_{fl} \Big/ \sum_{DHW\ Service\ 1}^{DHW\ Service\ N} Max\ Impact \times$

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	$RelevanceWF \times BuildingtypeWF \times LocationWF\,;\ \sum_{Cooling\ Service\ 1}^{Cooling\ Service\ N} Impact_{fl} \Big/ \sum_{Cooling\ Service\ 1}^{Cooling\ Service\ N} Max\ Impact \times RelevanceWF \times DWF;\ \sum_{CV\ Service\ 1}^{CV\ Service\ N} Impact_{fl} \Big/ \sum_{CV\ Service\ 1}^{CV\ Service\ N} Max\ Impact \times RelevanceWF \times DWF;\ \sum_{Lighting\ Service\ 1}^{Lighting\ Service\ N} Impact_{fl} \Big/ \sum_{Lighting\ Service\ 1}^{Lighting\ Service\ N} Max\ Impact \times RelevanceWF \times DWF;\ ;\ \sum_{electricity\ Service\ 1}^{electricity\ Service\ N} Impact_{fl} \Big/ \sum_{electricity\ Service\ 1}^{electricity\ Service\ N} Max\ Impact \times RelevanceWF \times DWF;\ \sum_{DE\ Service\ 1}^{DE\ Service\ N} Impact_{fl} \Big/ \sum_{DE\ Service\ 1}^{DE\ Service\ N} Max\ Impact \times RelevanceWF \times DWF\,;\ \sum_{EV\ Service\ 1}^{EV\ Service\ N} Impact_{fl} \Big/ \sum_{EV\ Service\ 1}^{EV\ Service\ N} Max\ Impact \times RelevanceWF \times DWF;\ \sum_{MC\ Service\ 1}^{MC\ Service\ N} Impact_{fl} \Big/ \sum_{MC\ Service\ 1}^{MC\ Service\ N} Max\ Impact \times RelevanceWF \times DWF)$
Unit of measurement	%
Related UCs	UC7.8
Related demo cases	DC20
Related energy apps	SRI

KPI information	
KPI ID	*KPI_37*
KPI name	Health & wellbeing *for the building*
Impact Category and aspect	*Energy, Energy Performance*
Description	This KPI calculates the impact factor of the smart readiness indicator related to the health & wellbeing for the building of reference upon the user's request. Based on the SRI methodology described in deliverable D7.1, this impact factor is the average of the percentage of impact of the 9 different domains (namely heating, DHW, cooling, controlled ventilation, lighting, dynamic building envelope, electricity electric vehicle charging, monitoring and control) of the assessment on health & well-being.

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	For each domain, the user specifies the functionality levels of several services within the domain based on the characteristics of the services and respective systems of the building. The functionality level of each service corresponds to an impact rating, which is then divided by the maximum rating of the service. The resulting percentage for each service is then averaged for each domain. Finally, the percentage for each domain is multiplied with a relevance factor (0 or 1) and the domain weighting factor (DWF) which depends on the building's location and the building's type (residential or non-residential) both of which are also specified in the SRI methodology.
Formula	$Impact_{health\&welbeing} = AVERAGE\left(\sum_{Heating\ Service\ 1}^{Heating\ Service\ N} Impact_{fl} \middle/ \sum_{Heating\ Service\ 1}^{Heating\ Service\ N} Max\ Impact \times RelevanceWF \times DWF; \sum_{DHW\ Service\ 1}^{DHW\ Service\ N} Impact_{fl} \middle/ \sum_{DHW\ Service\ 1}^{DHW\ Service\ N} Max\ Impact \times RelevanceWF \times DWF; \sum_{Cooling\ Service\ 1}^{Cooling\ Service\ N} Impact_{fl} \middle/ \sum_{Cooling\ Service\ 1}^{Cooling\ Service\ N} Max\ Impact \times RelevanceWF \times DWF; \sum_{CV\ Service\ 1}^{CV\ Service\ N} Impact_{fl} \middle/ \sum_{CV\ Service\ 1}^{CV\ Service\ N} Max\ Impact \times RelevanceWF \times DWF; \sum_{Lighting\ Service\ 1}^{Lighting\ Service\ N} Impact_{fl} \middle/ \sum_{Lighting\ Service\ 1}^{Lighting\ Service\ N} Max\ Impact \times RelevanceWF \times DWF; \sum_{electricity\ Service\ 1}^{electricity\ Service\ N} Impact_{fl} \middle/ \sum_{electricity\ Service\ 1}^{electricity\ Service\ N} Max\ Impact \times RelevanceWF \times DWF; \sum_{DE\ Service\ 1}^{DE\ Service\ N} Impact_{fl} \middle/ \sum_{DE\ Service\ 1}^{DE\ Service\ N} Max\ Impact \times RelevanceWF \times DWF; \sum_{EV\ Service\ 1}^{EV\ Service\ N} Impact_{fl} \middle/ \sum_{EV\ Service\ 1}^{EV\ Service\ N} Max\ Impact \times RelevanceWF \times DWF; \sum_{MC\ Service\ 1}^{MC\ Service\ N} Impact_{fl} \middle/ \sum_{MC\ Service\ 1}^{MC\ Service\ N} Max\ Impact \times RelevanceWF \times DWF\right)$
Unit of measurement	%
Related UCs	UC7.8
Related demo cases	DC20
Related energy apps	SRI

KPI information	
KPI ID	*KPI_38*

KPI name	*Maintenance & fault prediction for the building*
Impact Category and aspect	*Energy, Energy Performance*
Description	This KPI calculates the impact factor of the smart readiness indicator related to maintenance & fault prediction for the building of reference upon the user's request. Based on the SRI methodology described in deliverable D7.1, this impact factor is the average of the percentage of impact of the 9 different domains (namely heating, DHW, cooling, controlled ventilation, lighting, dynamic building envelope, electricity electric vehicle charging, monitoring and control) of the assessment on maintenance & fault prediction. For each domain, the user specifies the functionality levels of several services within the domain based on the characteristics of the services and respective systems of the building. The functionality level of each service corresponds to an impact rating, which is then divided by the maximum rating of the service. The resulting percentage for each service is then averaged for each domain. Finally, the percentage for each domain is multiplied with a relevance factor (0 or 1) and the domain weighting factor (DWF) which depends on the building's location and the building's type (residential or non-residential) both of which are also specified in the SRI methodology.
Formula	$Impact_{maintenance\&faultprediction} = AVERAGE\left(\sum_{Heating\ Service\ 1}^{Heating\ Service\ N} Impact_{fl} \Big/ \sum_{Heating\ Service\ 1}^{Heating\ Service\ N} Max\ Impact \times RelevanceWF \times DWF;\ \sum_{DHW\ Service\ 1}^{DHW\ Service\ N} Impact_{fl} \Big/ \sum_{DHW\ Service\ 1}^{DHW\ Service\ N} Max\ Impact \times RelevanceWF \times DWF;\ \sum_{Cooling\ Service\ 1}^{Cooling\ Service\ N} Impact_{fl} \Big/ \sum_{Cooling\ Service\ 1}^{Cooling\ Service\ N} Max\ Impact \times RelevanceWF \times DWF;\ \sum_{CV\ Service\ 1}^{CV\ Service\ N} Impact_{fl} \Big/ \sum_{CV\ Service\ 1}^{CV\ Service\ N} Max\ Impact \times RelevanceWF \times DWF;\ \sum_{Lighting\ Service\ 1}^{Lighting\ Service\ N} Impact_{fl} \Big/ \sum_{Lighting\ Service\ 1}^{Lighting\ Service\ N} Max\ Impact \times RelevanceWF \times DWF;\ \sum_{electricity\ Service\ 1}^{electricity\ Service\ N} Impact_{fl} \Big/ \sum_{electricity\ Service\ 1}^{electricity\ Service\ N} Max\ Impact \times RelevanceWF \times DWF;\ \sum_{DE\ Service\ 1}^{DE\ Service\ N} Impact_{fl} \Big/ \sum_{DE\ Service\ 1}^{DE\ Service\ N} Max\ Impact \times RelevanceWF \times DWF;\ \sum_{EV\ Service\ 1}^{EV\ Service\ N} Impact_{fl} \Big/ \sum_{EV\ Service\ 1}^{EV\ Service\ N} Max\ Impact \times RelevanceWF \times DWF;\ \sum_{MC\ Service\ 1}^{MC\ Service\ N} Impact_{fl} \Big/ \sum_{MC\ Service\ 1}^{MC\ Service\ N} Max\ Impact \times RelevanceWF \times DWF\right)$
Unit of measurement	%

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Related UCs	UC7.8
Related demo cases	DC20
Related energy apps	SRI

KPI information	
KPI ID	*KPI_39*
KPI name	*Information to occupants for the building*
Impact Category and aspect	*Energy, Energy Performance*
Description	This KPI calculates the impact factor of the smart readiness indicator related to information to occupants for the building of reference upon the user's request. Based on the SRI methodology described in deliverable D7.1, this impact factor is the average of the percentage of impact of the 9 different domains (namely heating, DHW, cooling, controlled ventilation, lighting, dynamic building envelope, electricity electric vehicle charging, monitoring and control) of the assessment on information to occupants. For each domain, the user specifies the functionality levels of several services within the domain based on the characteristics of the services and respective systems of the building. The functionality level of each service corresponds to an impact rating, which is then divided by the maximum rating of the service. The resulting percentage for each service is then averaged for each domain. Finally, the percentage for each domain is multiplied with a relevance factor (0 or 1) and the domain weighting factor (DWF) which depends on the building's location and the building's type (residential or non-residential) both of which are also specified in the SRI methodology.
Formula	$Impact_{information\ to\ occupants} =$ $AVERAGE(\sum_{Heating\ Service\ 1}^{Heating\ Service\ N} Impact_{fl} \Big/ \sum_{Heating\ Service\ 1}^{Heating\ Service\ N} Max\ Impact \times$ $RelevanceWF \times DWF\ ; \sum_{DHW\ Service\ 1}^{DHW\ Service\ N} Impact_{fl} \Big/ \sum_{DHW\ Service\ 1}^{DHW\ Service\ N} Max\ Impact \times$ $RelevanceWF \times DWF; \sum_{Cooling\ Service\ 1}^{Cooling\ Service\ N} Impact_{fl} \Big/ \sum_{Cooling\ Service\ 1}^{Cooling\ Service\ N} Max\ Impact \times$ $RelevanceWF \times DWF; \sum_{CV\ Service\ 1}^{CV\ Service\ N} Impact_{fl} \Big/ \sum_{CV\ Service\ 1}^{CV\ Service\ N} Max\ Impact \times$ $RelevanceWF \times$

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	$DWF; \sum_{Lighting\ Service\ 1}^{Lighting\ Service\ N} Impact_{fl} \Big/ \sum_{Lighting\ Service\ 1}^{Lighting\ Service\ N} Max\ Impact \times RelevanceWF \times DWF; \sum_{electricity\ Service\ 1}^{electricity\ Service\ N} Impact_{fl} \Big/ \sum_{electricity\ Service\ 1}^{electricity\ Service\ N} Max\ Impact \times RelevanceWF \times DWF; \sum_{DE\ Service\ 1}^{DE\ Service\ N} Impact_{fl} \Big/ \sum_{DE\ Service\ 1}^{DE\ Service\ N} Max\ Impact \times RelevanceWF \times DWF; \sum_{EV\ Service\ 1}^{EV\ Service\ N} Impact_{fl} \Big/ \sum_{EV\ Service\ 1}^{EV\ Service\ N} Max\ Impact \times RelevanceWF \times DWF; \sum_{MC\ Service\ 1}^{MC\ Service\ N} Impact_{fl} \Big/ \sum_{MC\ Service\ 1}^{MC\ Service\ N} Max\ Impact \times RelevanceWF \times DWF)$
Unit of measurement	%
Related UCs	UC_7_8
Related demo cases	DC20
Related energy apps	SRI

KPI information	
KPI ID	*KPI_40*
KPI name	*SRI of the building*
Impact Category and aspect	*Energy, Energy Performance*
Description	This KPI calculates the total smart readiness indicator of the building of reference upon the user's request. Based on the SRI methodology described in deliverable D7.1, this indictor derives as the weighted average of the impact factors calculated in KPIs 49 to 55
Formula	$SRI_{total} = KPI_{49} \times ImpactWeigthES + KPI_{50} \times ImpactWeigthFS + KPI_{51} \times ImpactWeigthComf + KPI_{52} \times ImpactWeigthConv + KPI_{53} \times ImpactWeigthHealth + KPI_{54} \times ImpactWeigthMC + KPI_{55} \times ImpactWeigthInf$

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Unit of measurement	% (or on a graded scale A to G)
Related UCs	UC_7_8
Related demo cases	DC20
Related energy apps	SRI

KPI information	
KPI ID	*KPI_41*
KPI name	*Time saving* to select the required renovation actions
Impact Category and aspect	*Economic,* Urban Planning, Local Energy Communities efficiency
Description	This indicator shows the ability of the application to reduce the time needed to select the required renovation actions
Formula	$\Delta T = T_{simul} - T_{ai}$ where ΔT - time saving, T_{simul} - time used to simulate 10 renovation cases with IDA ICE tool, T_{ai} - time used to simulated 10 renovation cases using AI based renovation support tool + 3 selected renovation cases simulated by ICE IDA
Unit of measurement	hour
Related UCs	UC_7_1, UC_7_2
Related demo cases	DC 19
Related energy apps	Advanced Renovation Support App

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KPI information	
KPI ID	*KPI_42*
KPI name	Flexibility on offer
Impact Category and aspect	Flexibility, DER activation
Description	This KPI calculates the potential of flexibility (modelled) compared to actual electricity consumption of each flexible asset/VPP during a period of analysis (e.g. a year, a set of characteristic days etc,).
Formula	$$FlexibilityOnOffer = \left(\frac{\sum_{t\in T} Flex_{t,Forecast}}{\sum_{t\in T} P_{t,Actual}}\right) \times 100$$ $Flex_{t,Forecast}$ is the forecasted flexibility potential during the metering period. $P_{t,Actual}$ is the actual energy consumption during the metering period. T is the total period of observation.
Unit of measurement	%
Related UCs	UC_6_4
Related demo cases	DC5-DC12-DC15-DC21-
Related energy apps	Flexibility Analytics and Consumer-Centric DR Optimization Application

KPI information	
KPI ID	*KPI_43*
KPI name	Flexibility on capacity
Impact Category and aspect	Flexibility, DER activation
Description	This KPI calculates the potential of flexibility (modelled) compared to nominal capacity of each flexible asset/VPP during a period of analysis (e.g. a year, a set of characteristic days etc,).

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Formula	$$FlexibilityOnCapacity = \left(\frac{\sum_{t\in T} Flex_{t,Forecast}}{T * P_{Capacity}}\right) \times 100$$ $Flex_{t,Forecast}$ is the forecasted flexibility potential during the metering period. $P_{Capacity}$ is the nominal capacity of the flexible asset/VPP. T is the total period of observation.
Unit of measurement	%
Related UCs	UC_6_4
Related demo cases	DC5-DC12-DC15-DC21
Related energy apps	Flexibility Analytics and Consumer-Centric DR Optimization Application

KPI information	
KPI ID	*KPI_44*
KPI name	Actual Flexibility Availability
Impact Category and aspect	Flexibility, DER activation
Description	This KPI calculates the actual flexibility activated compared to the forecast of flexibility (modelled) during a period of analysis (e.g. a year, a set of characteristic days etc,).
Formula	$$ActualFlexibilityAvailability = \left(\frac{\sum_{t\in T} Flex_{t,Actual}}{\sum_{t\in T} Flex_{t,Forecast}}\right) \times 100$$ $Flex_{t,Actual}$ is the actual flexibility activated during the metering period. $Flex_{t,Forecast}$ is the forecasted flexibility potential during the metering period. T is the total period of observation.
Unit of measurement	%
Related UCs	UC_6_5

Related demo cases	DC5-DC12-DC15-DC21
Related energy apps	Flexibility Analytics and Consumer-Centric DR Optimization Application

KPI information	
KPI ID	*KPI_45*
KPI name	Flexibility Request
Impact Category and aspect	Flexibility, DER activation
Description	This KPI calculates the flexibility requested triggered compared to the forecast of flexibility (modelled) during a period of analysis (e.g. a year, a set of characteristic days etc,).
Formula	$$FlexibilityRequest = \left(\frac{\sum_{t\in T} Flex_{t,Order}}{\sum_{t\in T} Flex_{t,Forecast}}\right) \times 100$$ $Flex_{t,order}$ is the flexibility requested from a flexible asset/ VPP during the metering period. $Flex_{t,Forecast}$ is the forecasted flexibility potential during the metering period. T is the total period of observation.
Unit of measurement	%
Related UCs	UC_6_5
Related demo cases	DC5-DC12-DC15-DC21
Related energy apps	Flexibility Analytics and Consumer-Centric DR Optimization Application

KPI information	
KPI ID	*KPI_46*

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KPI name	Flexibility Activation
Impact Category and aspect	Flexibility, DER activation
Description	This KPI calculates the actual flexibility activated compared to the flexibility requested during a period of analysis (e.g. a year, a set of characteristic days etc,).
Formula	$$FlexibilityActivation = \left(\frac{\sum_{t\in T} Flex_{t,Actual}}{\sum_{t\in T} Flex_{t,Order}}\right) \times 100$$ $Flex_{t,Actual}$ is the actual flexibility activated during the metering period. $Flex_{t,order}$ is the flexibility requested from a flexible asset/ VPP during the metering period. T is the total period of observation.
Unit of measurement	%
Related UCs	UC_6_5
Related demo cases	DC5-DC12-DC15-DC21
Related energy apps	Flexibility Analytics and Consumer-Centric DR Optimization Application

KPI information	
KPI ID	*KPI_47*
KPI name	Flexibility Override
Impact Category and aspect	Flexibility, DER activation
Description	This KPI calculates the non-delivery of flexibility compared to the flexibility requested during a period of analysis (e.g. a year, a set of characteristic days etc,).
Formula	$$FlexibilityOverride = \left(\frac{\sum_{t\in T} \lvert Flex_{t,Order} - Flex_{t,Actual} \rvert}{\sum_{t\in T} Flex_{t,Order}}\right) \times 100$$

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	$Flex_{t,Actual}$ is the actual flexibility activated during the metering period. $Flex_{t,order}$ is the flexibility requested from a flexible asset/ VPP during the metering period. T is the total period of observation.
Unit of measurement	%
Related UCs	UC_6_5
Related demo cases	DC5-DC12-DC15-DC21
Related energy apps	Flexibility Analytics and Consumer-Centric DR Optimization Application

KPI information	
KPI ID	KPI_48
KPI name	Actual Flexibility on Contract
Impact Category and aspect	Establishment of advanced Flexibility settlement and Remuneration Methods, Alternative (smart) contract types, Smart contract handling mechanisms
Description	This KPI calculates the actual flexibility activated per contract established on the flexibility marketplace during a period of analysis (e.g. a year, a set of characteristic days etc,).
Formula	$$ActualFlexContract = \left(\frac{\sum_{t\in T} Flex_{t,Actual}}{T * N_{contract}}\right)$$ $Flex_{t,Actual}$ is the actual flexibility activated (all contracts) during the metering period. $N_{contract}$ is the number of contracts established on the flexibility marketplace. T is the total period of observation.
Unit of measurement	KW
Related UCs	UC_6_10

Related demo cases	DC5-DC16
Related energy apps	DR Smart Contract Monitoring, Handling, Settlement and Remuneration Platform

KPI information	
KPI ID	KPI_49
KPI name	Flexibility Request on Contract
Impact Category and aspect	Establishment of advanced Flexibility settlement and Remuneration Methods, Alternative (smart) contract types, Smart contract handling mechanisms
Description	This KPI calculates the flexibility requested per contract established on the flexibility marketplace during a period of analysis (e.g. a year, a set of characteristic days etc,).
Formula	$$FlexRequestContract = \left(\frac{\sum_{t\in T} Flex_{t,Order}}{T * N_{contract}}\right)$$ $Flex_{t,order}$ is the flexibility requested (all contracts) during the metering period. $N_{contract}$ is the number of contracts established on the flexibility marketplace. T is the total period of observation.
Unit of measurement	KW
Related UCs	UC_6_10
Related demo cases	DC5-DC16
Related energy apps	DR Smart Contract Monitoring, Handling, Settlement and Remuneration Platform

KPI information	
KPI ID	KPI_50
KPI name	Revenue on Contract

Impact Category and aspect	Establishment of advanced Flexibility settlement and Remuneration Methods, Alternative (smart) contract types, Smart contract handling mechanisms
Description	This KPI calculates the average revenue per contract established on the flexibility marketplace during a period of analysis (e.g. a year, a set of characteristic days etc,).
Formula	$RevenueOnContract = \left(\frac{\sum_{t \in T}(Flex_{t,actual} * p, activation\ +\ Flex_{t,Forecast} * p, capacity)}{N_{contract}}\right)$ $Flex_{t,Actual}$ is the actual flexibility activated (all contracts) during the metering period. $Flex_{t,Forecast}$ is the forecasted available flexibility (all contracts) during the metering period. $p, activation$ is the price remuneration for the flexibility activated. $p, capacity$is the price remuneration for the flexibility capacity availability $N_{contract}$ is the number of contracts established on the flexibility marketplace. T is the total period of observation.
Unit of measurement	currency
Related UCs	UC_6_10
Related demo cases	DC5-DC16
Related energy apps	DR Smart Contract Monitoring, Handling, Settlement and Remuneration Platform

KPI information	
KPI ID	KPI_51
KPI name	Penalty on Contract
Impact Category and aspect	Establishment of advanced Flexibility settlement and Remuneration Methods, Alternative (smart) contract types, Smart contract handling mechanisms

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Description	This KPI calculates the average penalty per contract established on the flexibility marketplace during a period of analysis (e.g. a year, a set of characteristic days etc,).
Formula	$$PenaltyOnContract = \left(\frac{\sum_{t\in T}(Flex_{t,override} * p, penalty)}{N_{contract}}\right)$$ $Flex_{t,override}$ is the flexibility non delivered (all contracts) during the metering period. $p, penalty$ is the penalty price for non-delivery of the flexibility requested. $N_{contract}$ is the number of contracts established on flexibility marketplace. T is the total period of observation.
Unit of measurement	currency
Related UCs	UC_6_10
Related demo cases	DC5-DC16
Related energy apps	DR Smart Contract Monitoring, Handling, Settlement and Remuneration Platform

KPI information	
KPI ID	KPI_52
KPI name	Profit on Contract
Impact Category and aspect	Establishment of advanced Flexibility settlement and Remuneration Methods, Alternative (smart) contract types, Smart contract handling mechanisms
Description	This KPI calculates the average profit per contract established on the flexibility marketplace during a period of analysis (e.g. a year, a set of characteristic days etc,).
Formula	$$ProfitOnContract = \left(\frac{\sum_{t\in T}(Revenue_t - Penalty_t)}{N_{contract}}\right)$$ $Revenue_t$ is the revenue for flexibility activated (all contracts) during the metering period.

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	$Penalty_t$ is the penalty for flexibility override (all contracts) during the metering period. $N_{contract}$ is the number of contracts established on the flexibility marketplace. T is the total period of observation.
Unit of measurement	currency
Related UCs	UC_6_10
Related demo cases	DC5-DC16
Related energy apps	DR Smart Contract Monitoring, Handling, Settlement and Remuneration Platform

KPI information	
KPI ID	*KPI_53*
KPI name	Payback Period
Impact Category and aspect	Economic
Description	The payback period is the length of time it takes to recover the cost of an investment or the length of time an investor needs to reach a breakeven point. Shorter paybacks mean more attractive investments, while longer payback periods are less desirable.
Formula	$PP = \left(\frac{Investment}{Annual\ Income}\right)$
Unit of measurement	Years
Related UCs	UC_5_10
Related demo cases	DC8
Related energy apps	Performance Monitoring/Forecasting and Predictive Maintenance Portfolio Analytics and Management Application

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KPI information	
KPI ID	*KPI_54*
KPI name	Return on Investment
Impact Category and aspect	Economic
Description	Return on investment (ROI) is a performance measure used to evaluate the efficiency or profitability of an investment or compare the efficiency of a number of different investments. ROI tries to directly measure the amount of return on a particular investment, relative to the investment's cost
Formula	$ROI = \left(\frac{Current\ Value\ of\ Investment - Cost\ of\ Investment}{Cost\ of\ Investment}\right)$
Unit of measurement	%
Related UCs	UC_5_10
Related demo cases	DC8
Related energy apps	Performance Monitoring/Forecasting and Predictive Maintenance Portfolio Analytics and Management Application

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