REEFLEX

REplicable, interoperable, cross-sector solutions and Energy services for demand side FLEXibility markets

Deliverable nº:	**D2.1**
Deliverable name:	**PMV framework and KPIs**
Version:	1.**0**
Release date:	12/01/2024
Dissemination level:	**PU (Public)**
Author:	**CARTIF**

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Document history:

Version	Date of issue	Content and changes	Edited by
0.1	21/07/2023	First TOC.	CARTIF
0.2	25/10/2023	General content.	CARTIF
3	07/11/2023	General content, competitors analysis	CERTH
0.4	10/11/2023	General content, competitors analysis	SUITE5
0.5	13/11/2023	General content.	CARTIF
0.51	15/11/2023	General content, competitors analysis	ARC
0.52	16/11/2023	General content, competitors analysis	BETT
0.53	16/11/2023	General content.	CARTIF
0.8	18/12/2023	General content.	CARTIF
0.85	22/12/2023	General content.	CARTIF
0.9	03/01/2024	Last review	CIRCE / CARTIF
1.0	11/01/2024	Definitive version	CARTIF

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Abbreviations and Acronyms

Acronym	Description
PMV	Performance Measurement and Verification
PVP	Performance Verification Plan
UC	Use Case
IP	Innovation Pillar
KPI	Key Performance Indicator
IPMVP	International Performance, Measure and Verification Protocol
M&V	Measure and Verification
ECM	Energy Conservation Measure
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ISO	International Organization for Standardization
DSF	Demand Side Flexibility
FEMP	Federal Energy Management Programme
UMP	Uniform Methods Project
EMS	Energy Management System
API	Application Programming Interface
MQTT	Message Queuing Telemetry Transport
BIM	Building Information Modelling
LCA	Life Cycle Analysis
LCC	Life Cycle Cost
LCI	Life Cycle Inventory
ICT	Information and Communication Technologies
SRT	Self-Reporting Tool
SDG	Sustainable Development Goals
SRI	Smart Readiness Indicator
BMU	Universal Battery Management system
BMS	Battery Management System
ML	Machine Learning

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Acronym	Description
DL	Deep Learning
DC	Direct Current
AC	Alternating Current
NILM	Non-Intrusive Load Monitoring
DSO	Distribution System Operator
TSO	Electricity System Operator
P2P	Peer to Peer
RES	Renewable Energy Sources
BSP/BRP	Balancing Service Provider / Balance Responsible Party
EV	Electric Vehicle
PV	Photovoltaic

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Executive summary

Deliverable 2.1 PMV framework and KPIs is the document where the work about the definition of the methodology for the Performance and Verification Plan (PVP) of the REEFLEX project is described (Task 2.2). In addition, on this deliverable are also included the definitions for the KPIs that would be used in the project to evaluate the developed technologies and how they affect in the global performance of the different Use Cases and Demo Sites.

The work shown on this deliverable will be used as basis for future tasks of the project. More specifically in the work package 6 (WP6), the work to be done in the Task 6.6 will be based on the results of this deliverable and included in deliverables D6.3 and D6.4.

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1 Introduction

This document describes the methodology of calculation of Key Performance Indicators (KPIs). These KPIs will be used to assess the effectiveness of the solutions proposed by REEFLEX by evaluating KPIs before and after their technical implementations in the Demo Sites. As well, in this document it is explained how the procedure follows the directives from the International Performance and Verification Plan.

1.1 Structure of the deliverable

This deliverable is divided into six main chapters which compound the document as follows:

- Chapter 1. This chapter includes an introduction of the document and its relation to other Work Packages of the project.
- Chapter 2. Description of which tools, described as Innovation Pillars (IPs) of the project, are going to be implemented on Demo Sites. These tools are going to be evaluated thanks to the defined Use Cases (UCs). UCs relate every IP with every Demo Site.
- Chapter 3. A description on several Measure and Verification protocols is provided, highlighting the selection and use of the International Performance and Verification Protocol (IPMVP). This protocol is the basis for the methodology of evaluation of the tools and services and how the KPIs have been defined to evaluate them.
- Chapter 4. KPIs are described not only for each IP but also in a general way. These general KPIs are defined to evaluate general aspects that cannot be evaluated through the IPs' KPIs. In addition, Contingency KPIs are described in this section.
- Chapter 5. Comparison among the project tools with others similar ones present in the market.
- Chapter 6. Conclusions.

1.2 Relation to other Work Packages, Tasks and Deliverables

The outputs of this deliverable are a fundamental part of "MS3- Definition of requirements for the PMV and KPIs gathering and selection of most applicable ones for REEFLEX needs". This document is also very close related with D2.2. and D2.4. Consequently, this deliverable gathers information from T2.1., T2.2. and T2.5.

This deliverable feeds all the Tasks in Work Package 6 in the sense this document is basis for the definition of the monitoring plan in Task T6.1. Tasks T6.2., T6.3., T6.4. and T6.5. will follow the plan defined in T2.1, T2.3 and T6.1 so subsequently are related with D2.1. Finally, T6.6 will calculate the KPIs defined in D2.1. The outputs of these Tasks will be included in D6.3. and D6.4.

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2 Overview of Use Cases and technological innovations within the REEFLEX PROJECT

This section describes the three main assets for the REEFLEX project, firstly describes which are the demo sites on the project, then the IPs or tools developed in the project and finally how these tools are combined into UCs.

2.1 Definition of the Demo Sites

In the REEFLEX project four Demo Sites have been chosen as the places on which the tools developed in the project (IPs) will be tested. There are four main locations for these Demo Sites (known as Pilots) which are Pilot 1.-Spain, Pilot 2.-Greece, Pilot 3.- Switzerland and Pilot 4.-Bulgaria. Following a brief description of each of them is provided. More detailed description can be consulted in Deliverable 2.5. Each Pilot site is divided into buildings and Clusters.

2.1.1 Pilot 1.- Spain.

It is composed by three different buildings located in Zaragoza, in the North-East of Spain, and a fourth location in northern Spain, listed following;

Cluster 1) CIRCE headquarters, main offices, which are equipped with a complete monitoring and control system for electricity consumption, lighting and HVAC (for heating/cooling) regulation, a photovoltaic installation, a battery storage system and 3 EV charging points (2 unidirectional, and one bidirectional). Living lab is CIRCE's electrical/electronic laboratory, where, among other things, power electronics systems are developed for the testing of storage systems (BESS) or EV charging installations. This lab has a DC microgrid to test different hardware and software components.

Cluster 2) URBENER headquarters. The URBENER headquarters are situated in Zaragoza on the fifth level of Coso Street 34. The structure has both residential and commercial use (i.e., offices). The first seven levels are reserved for offices, while the last five are apartments.

Cluster 3) ARCELOR factory. Currently is operating in the interruptibility services (until now, the service provided by large consumers that is closer to demand management), providing an ad-hoc value and important know-how to the activities to be developed in REEFLEX. Besides it, in ARCELOR MITTAL facilities, the industrial NILM will be tested.

Cluster 4) ZAVI dwellings. The demo building is one of the two residential buildings located in Actur Rey Fernando District named Alejandro Casona – Margarita Xirgú, built in 1992 with 96 dwellings.

2.1.2 Pilot 2.- Greece.

The Greek demo site is composed of a set of 50 residential buildings, 3 energy retail stores one large commercial facility, all of them located in Thessalonica.

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Cluster 1) Residential – WVT Private apartments. Composed by fifty residential apartments have a maximum occupancy of two to three (2-3) people per unit on average and have a total floor area of three thousand (3000) square meters (60 m2 each).

Cluster 2) INNO retail stores. The three tertiary retail stores can accommodate a maximum of three (3) employees, who can serve 120 customers each day when they are open six days a week. The overall floor area is seventy square meters.

Cluster 3) WVT and INNO commercial site. The large commercial facility can accommodate a maximum of five (5) employees, who can serve 150 visitors each day, when they are open six days a week. The overall floor area is two hundred square meters.

2.1.3 Pilot 3.- Switzerland.

The Swiss demo site is taking place in the urban Via Motta District in Massagno, a suburban local Energy Community (EC). The Swiss demo site in REEFLEX project is composed of an elderly care home, a warehouse, a large engineering & legal office building and a set of 5 residential buildings.

Cluster 1) Residential – Elderly care home. The Swiss pilot's elderly care home residential building accommodates 60 elderly residents plus approx. 90 workers and have a total floor area of four thousand five hundred square meters.

Cluster 2) Industrial – Via Motta warehouse. The Swiss pilot's Industrial facility (warehouse) have a maximum occupancy of five people on average and have a total floor area of two thousand square meters.

Cluster 3) Commercial – Via Motta offices. The Swiss pilot's office building accommodates an engineering and a legal office have a maximum occupancy of fifty people on average and have a total floor area of one thousand two hundred fifty square meters.

Cluster 4) Residential – Via Motta urban district. The Swiss pilot's five residential apartments have similar characteristics and several minor technical and energy characteristics differentiated that create plurality in the demo site outline. The investigated residential buildings (five in total) have a maximum occupancy between 3-35 people per unit.

2.1.4 Pilot 4.- Bulgaria.

The Bulgarian demo site is composed of three data centres located in Sofia (two of them) and in Montana, each of them composes a Cluster.

Cluster 1) Commercial - Data Center A. The Bulgarian pilot's Data Center A has a total floor area of two thousand five hundred square meters; the conditioned area is two thousand (2000) square meters.

Cluster 2) The Bulgarian pilot's Data Center B has a total floor area of one thousand two hundred fifty square meters; the conditioned area is nine hundred ninety square meters.

Cluster 3) The Bulgarian pilot's Data Center C has a total floor area of eight hundred square meters

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2.2 Definition of the Innovation Pillars

As commented in previous sections the Innovation Pillars cover the technological developments that are being developed and tested in the REEFLEX project. They are the core concept of the idea behind the project. IPs are divided into three main groups and subsequently split into several technologies. A more detailed description of each of the IPs can be found in section 5.

IP1. Interoperability and data exchange platform.

- IP1.1. REEFLEX Platform: data exchange, handling and interoperability.
- IP1.2. VERIFY: Web based platform enabling LCA and LCC of projects (Life Cycle Assessment and Life Cycle Cost).
- IP1.3. USE: Platform enabling uniform evaluation of projects.
- IP1.4. Flexibility potential classification for any given asset.

IP2. Optimal management and flexibility potential.

- IP2.1. Second-life batteries as flexibility assets.
- IP2.2. Predictive flexibility potential and operation of distributed devices.
- IP2.3. Non-Intrusive Load Monitoring (NILM) techniques for large consumers' load disaggregation.
- IP2.4. Innovative inverters for storage systems and electric vehicles (V2G)
- IP2.5. Algorithms for optimal management of the grid.

IP3. Connection and interactions with flexibility markets.

- IP3.1. End-users' potential flexibility calculation and aggregation.
- IP3.2. Calculation of DSO flexibility needs.
- IP3.3. Optimal market selection.
- IP3.4. P2P and bilateral energy exchange add-on platform.

2.3 Definition of the Use Cases

Use Cases are the particular implementation of the IPs on Demo Sites. They are group into eight different categories as follows:

UC1. Microgrids development to facilitate end-user participation in the flexibility market.

UC2. Disaggregation: dealing with large consumers.

UC3. Aggregation tasks facilitating market flexibility.

UC4. Long-term reservation of assets for short-term local flexibility markets.

UC5. Participation in short-term local flexibility markets with Day-ahead and Intraday Continuous Markets Integration.

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UC6. Increasing economic performance of large consumers.

UC7. Participation in flexibility markets via EV chargers and fleet.

UC8. Flexibility in buildings with fixed schedules.

These Use Cases are implemented in Demo Sites as stated in the ***Table 1***, where F means frontrunner (the Use Case will be implemented on the Demo Site) and R means Replicator.

Use Cases led and replicated in the main demonstrators	**Spain**	**Greece**	**Switzerland**	**Bulgaria**
UC1. Microgrids development to facilitate end-user participation in the flexibility market.	**F**	**R**	**R**	
UC2. Disaggregation: dealing with large consumers	**R**	**F**		**R**
UC3. Aggregation tasks facilitating market flexibility.	**F**			**R**
UC4. Long-term reservation of assets for short-term local flexibility markets	**R**	**R**	**F**	**R**
UC5. Participation in short-term local flexibility markets with Day-ahead and Intraday Continuous Markets Integration.	**R**	**R**	**F**	**R**
UC6. Increasing economic performance of large consumers.	**R**	**R**		**F**
UC7. Participation in flexibility markets via EV chargers and fleet.	**R**	**F**	**R**	
UC8. Flexibility in buildings with fixed schedules	**F**	**R**	**R**	

Table 1: Relations among Use Cases and Demo Sites.

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3 Definition of the methodology for the Measure and Verification

This section shows the definition of the PMV concept and the most common PMV protocols or calculation procedures. Finally, this section justifies the selection of the IPMVP protocol.

3.1 Definition of the PMV concept and its necessity

In order to evaluate and estimate the Energy savings produced in a building or service, and other kind of savings/improvements, it is necessary the use and adopt a reliable protocol. In fact, the energy savings are not directly measurable. What users can do is comparing two energy consumptions of a building in different conditions, for example before and after some refurbishment works or the implementation of other energy conservation measures (ECM). For example, the introduction of new energy savings services or applications. In this way several measure and verification protocols are presented in the market such as the International Performance, Measurement and Verification Protocol (IPMVP). The application of these measurement and verification protocols help the users in the estimation of the energy savings in a reliable way.

The main purposes of Measure and Verification protocols are the following:

- Increase energy savings.
- Document financial transactions.
- Enhance financing for efficiency projects.
- Improve engineering design and facility operations and maintenance.
- Manage energy budgets.
- Convince building owners to carry out installation of Energy Conservation Measures (ECM)
- Increase the confidence on Energy Performance Contracts (EPC)

3.2 Different PMV protocols

3.2.1 IPMVP

The International Performance Measure and Verification Protocol [1] (from now IPMVP) was born in 1994 in the U. S. Department of Energy. They started working with industry on the definition of a consensus to measure the investments on efficiency. After several iterations among years, today the protocol defines several steps to evaluate the energy savings produced in a building by the installation or substitution of new ECM. The protocol defines how measurements have to be taken, how to calculate the energy savings and its accuracy and confidence level.

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The protocol defines the following general and basic energy savings formulation:

Energy savings = Adjusted to Baseline period energy – Reporting period energy

+/- Adjustments

As seen in the previous expression, two different periods are used for the energy savings calculation, they are defined as follows:

- Baseline period: it is the period of time before the implementation of the ECM on which energy consumption, other characteristics of the building and time-varying conditions (for example, the external whether conditions) are measured. These measurements are treated as independent variables, while the energy consumption is the dependent variable. This means that energy consumption is considered to be affected by the rest of the measured variables. In this period, a mathematical model of the behaviour of the building is fitted using information on dependent and independent variables.
- Retrofitting period: is the period of time on which the refurbishment works, application of the ECMs, deployment of the services is done.
- Reporting period: is the period of time after the retrofitting period is finished. In this period the same independent and dependent variables are measured in the same way as the base line period.

Energy savings are computed the difference of the observed energy consumed in the reporting period and the same quantity predicted by the model which was fitted during the baseline period A graphic representation of this can be seen in the following figure.

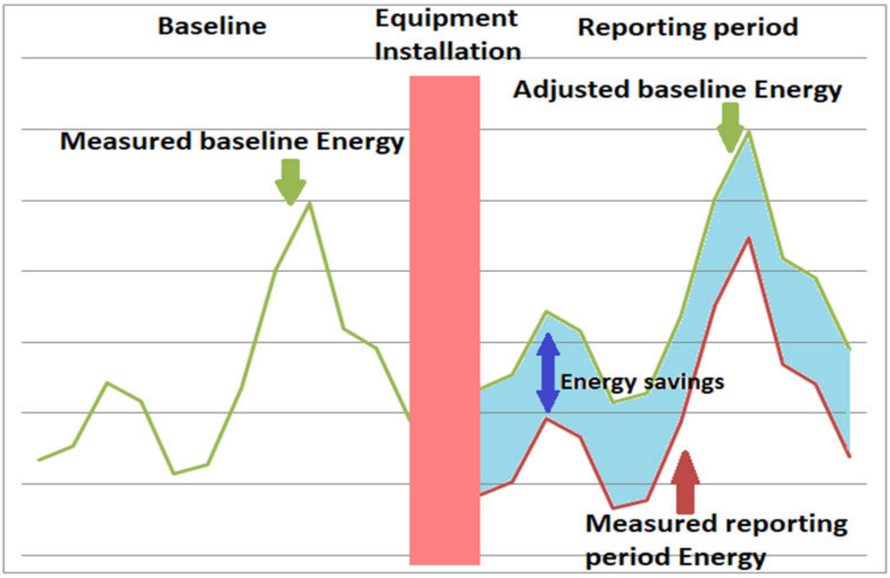

Figure 1. Energy consumption in the baseline and reporting periods.

The IPMP establishes four different options for the calculation of the mathematical model on its methodology regarding the boundaries of the ECM and the availability of measurements.

- Option A: Key performance measurement. Savings are determined by measuring the performance parameters that will have the higher effect on the savings calculation.

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Savings are calculated by combining measured values with estimated values. Measurement frequency ranges are taken from short-term to continuous depending on the expected variations in the measured parameter and the length of the reporting period. The same variables measured for the baseline must be measured for the reporting period. Any remaining parameters are estimated, using historical data, manufacturers specifications or engineering calculations.

- Option B: All parameters measurement. Savings are determined by measuring energy use and all variables affecting energy use within the energy conservation measure (ECM) boundary. Measurement frequency ranges are taken from short-term to continuous depending on the expected variations in the measured parameter and the length of the reporting period. The option B provides greater certainty of savings than Option A but it is more expensive.

- Option C: Whole facility, continuous measurement of all facility's energy consumption. Savings are determined by measuring energy at the whole facility or sub-facility level. It is used when expected savings are high compared to site energy use and measurement periods are long. Continuous measurement of the facility's energy use during the reporting period. Usually makes use of existing meters and/or energy invoices. An energy model using techniques such as regression is developed spanning the baseline period, which is adjusted for the post-retrofit period (reporting). The challenges for the Option C are to identify and incorporate all routine and non-routine adjustments, also ensuring that savings are large enough (approximately 10%) when compared to the whole energy consumption.

- Option D: Calibrated simulation. Savings are determined by simulations. Savings are determined through simulation of the energy use at the whole facility or sub-facility level. Simulations routines are demonstrated to accurately model actual energy performance measured at the facility. Computer Simulation Software is used to predict energy use. ECMs can be evaluated as a group or individually. Simulations need to be calibrated against actual energy use. This option is used when baseline data does not exist (for example in new construction buildings). The challenges are to develop an accurate simulation and to calibrate it. Specific software modelling skills and careful documentation are required. Sometimes is the most expensive.

A brief summary on how to choose among the 4 options proposed by IPMP is shown in Figure 2.

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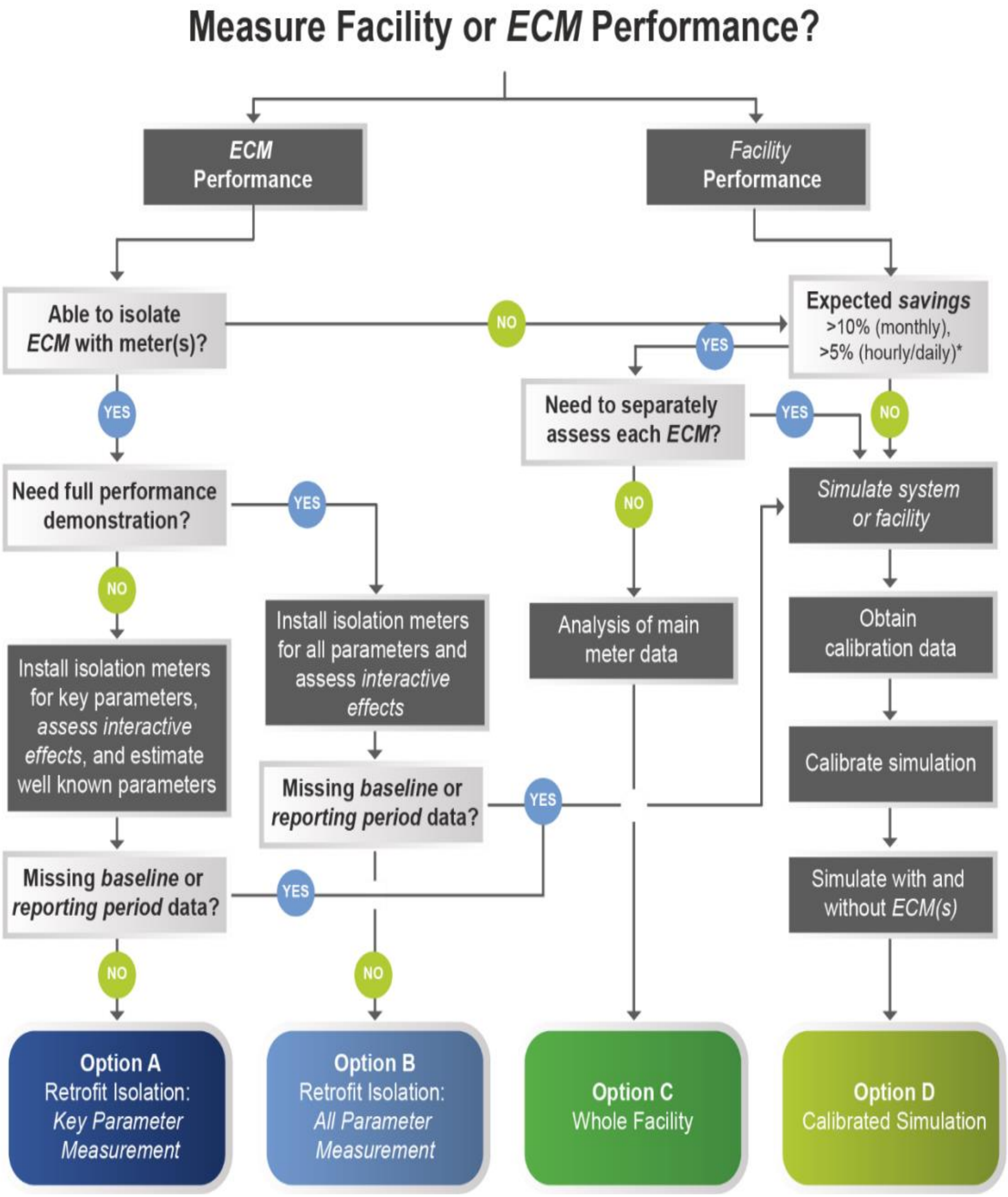

Figure 2. Selection of the correct option for IPMP.

3.2.2 ASHRAE Guideline 14

ASHRAE Guideline 14 [2] is officially known as "ASHRAE Guideline 14-2023 Measurement of Energy, Demand, and Water Savings" and was originally developed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). The first version of the protocol came out in 2002, from that moment the manual has been updated regularly to include current practices and new technologies. Even though the main purpose and philosophy for the application of the protocol is very similar to the previous one, the guideline in this case differences among three possible approaches:

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1. Whole Building Approach; it is used when data are available for both periods, pre-retrofitting and post-retrofitting. Usually, it uses data from general meters or monthly billing, defining the methodology to use them in the process. On some occasions, data can be measured continuously or in other frequency of recordings, for example, hourly, daily, weekly. This approach is used when the global building performance is calculated. This approach is divided into two possible paths depending on the continuity of data and possible gaps.
   - Whole Building Prescriptive Path. This path is most appropriate where the expected savings are greater than 10% of the measured energy use or demand and where the data are continuous, complete with no data points to be excluded. Whole Building
   - Performance Path. This path is most appropriate where the data are not continuous, have gaps and are expected to have similar problems in the post-retrofit period

   A flowchart for selecting one of these paths is shown in ***Figure 3***.

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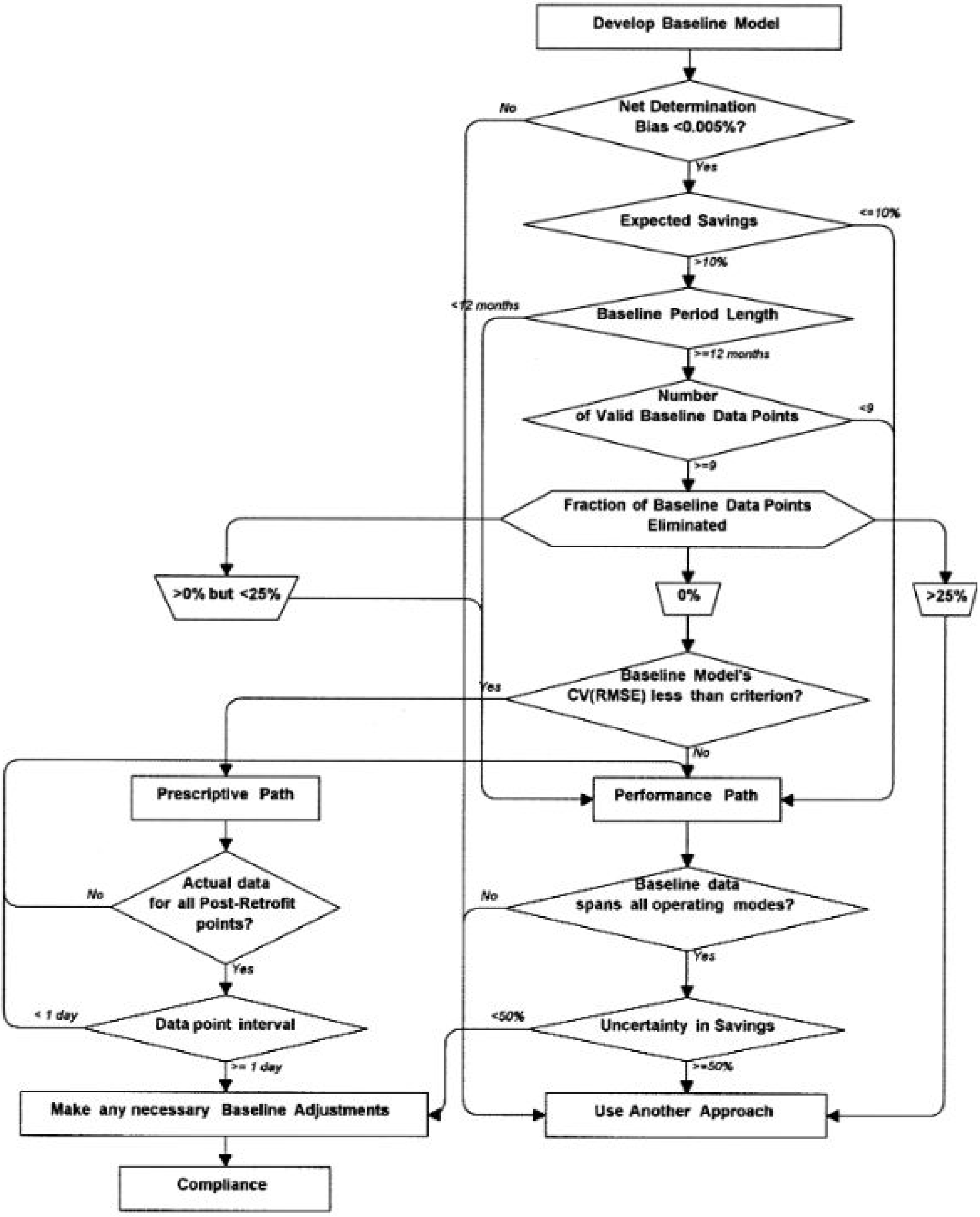

Figure 3. Flowchart for whole building approach.

2. Retrofit Isolation Approach. This approach is used when data about energy consumption can be measured in the equipment for a post-installation for a short-term period or continuously over time. It is used when the whole building path is not appropriated and savings come from a specific equipment and also when energy savings can be determined measuring a subsystem or equipment. This approach is described in ***Figure 4***.

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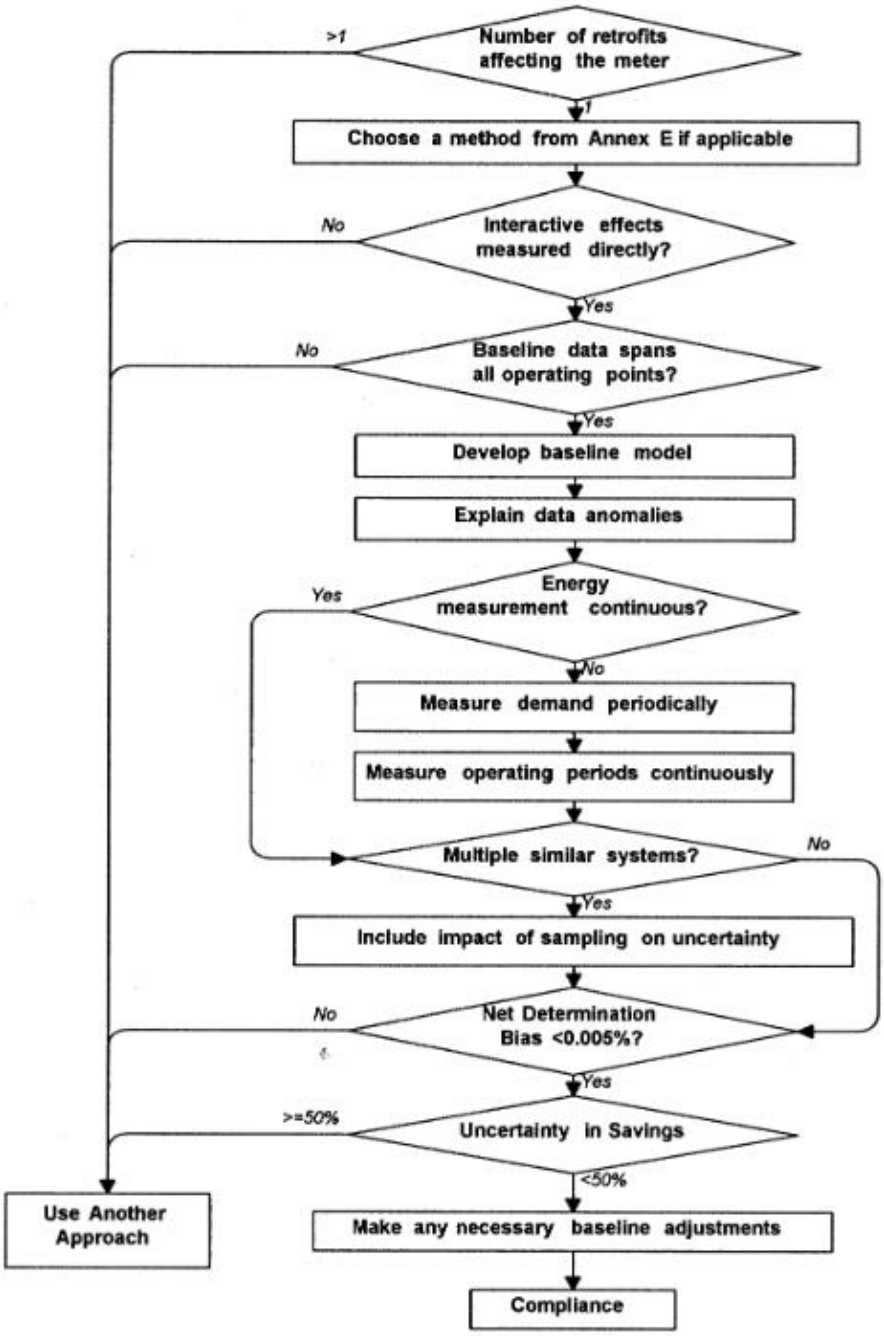

Figure 4. Flow chart for retrofit isolation approach performance path.

3. Whole Building Calibrated Simulation Approach (Calibrated Simulation). It is used when the building behaviour is calculated or emulated by the use of simulation software. It is very useful when there are many interactions among energy end-uses and measures. Also, it Is commonly used when no data from the baseline are available or savings cannot be calculated by comparison of before and after measurements. This method is used when data about whole building consumption is available but savings are desired from individual retrofits as well. This approach is described in ***Figure 5***.

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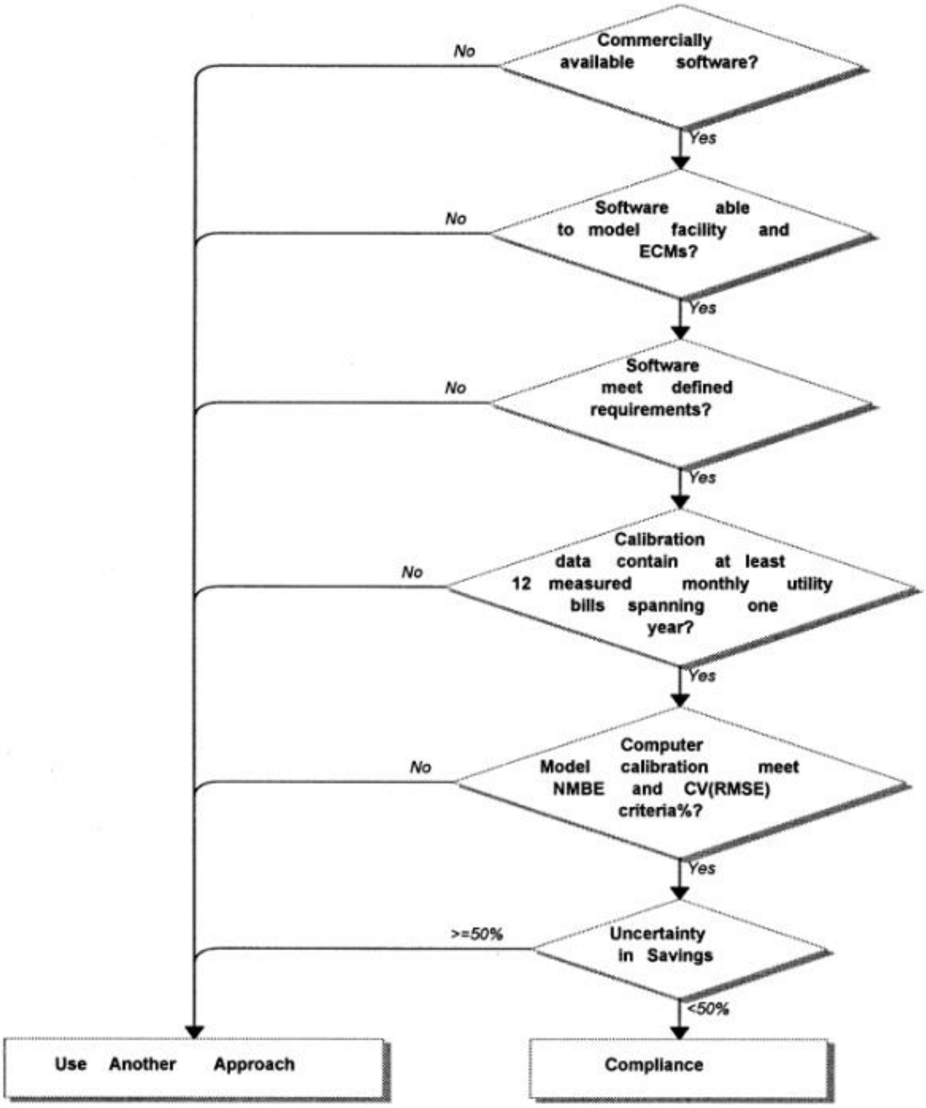

Figure 5. Flow chart for whole building calibrated simulation performance path.

For all of the approaches the protocol stablishes several rules for the calculation of savings, measurement uncertainty, expected accuracy, etc... The main calculation, energy savings, is based in measuring the energy consumption in the pre-retrofit period and in the post-retrofit period to calculate energy savings.

3.2.3 Other PMV protocols.

There are other PMV protocols defined by several institutions such as The **Federal Energy Management Programme** (FEMP [3]). This Department of Energy in the U. S. programme is focused in the energy consumption reduction of the federal agencies. To achieve this target the FEMP defines six steps to measure and verify savings:

1. Allocate Project Risks and Responsibilities.
2. Develop a Project-Specific M&V Plan.
3. Define the Baseline.

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4. Install and Commission Equipment and Systems.
5. Conduct Post-Installation Verification Activities.
6. Perform Regular-Interval M&V Activities.

ISO 50001 [4] is an international standard created by the International Organization for Standardization (ISO) which aims is not the proper definition of a M&V plan or protocol but the reduction of energy consumption, energy costs and their greenhouse gas emissions. It supports companies and organizations to use energy in a more efficient way by the implementation of an Energy Management System (EMS) and defines the requirements for implementing and maintaining it. As mentioned it is not a M&V protocol but follows definitions and procedures to evaluate energy consumption of an asset and how to reduce its consumption.

Other M&V protocols are defined by companies or organizations for specific buildings, assets or facilities. Commonly they depend on the needs from the users to evaluate energy consumption and how to achieve and evaluate the energy consumption reduction. While they are often defined on an ad-hoc basis, they generally follow similar guidelines to the ones previously established. This is the case of the **Uniform Methods Project** (UMP) which establishes twenty-four different protocols for M&V based on the building use; commercial, residential, combined residential and commercial and industrial. It is based on a particular case of the IPMVP but it includes processes to aggregate savings from individual projects and evaluate their impacts at a program level.

3.3 Selection of the IPMVP

As mentioned, IPMVP is one of the most used Measure and Verification protocols. Its definition and specifications cover all the needs of the REEFLEX project regarding the different sets of KPIs are going to be calculated in the project. Furthermore, the project benefits from the substantial experience of some partners in implementing IPMVP [5][6], making its selection highly advantageous. In section 4, detailed information on how KPIs have been defined is provided. These KPIs are the basis for the Measurement and Verification Plan and its implementation. Note that several KPIs will be calculated, not all of them related to energy saving (as the protocol is defined for) but for evaluating services.

3.4 Description of the Methodology for the PMV followed in REFFLEX

In the REEFLEX project the Measure and Verification process follows the basis of the International Performance Measure and Verification Protocol (IPMVP) but customized to make it more accurate to the needs of the project (as mentioned before we are not evaluating just energy savings). As it is explained in the section 4, in the project several KPIs have been defined, depending on what is been evaluated, Innovation Pillar, Use Case or Whole solution (General). As the scope of each of them is different, it will be defined different methods to evaluate them and calculate their associated KPIs, see section 4. This evaluation also depends on the availability of data; on the one hand whether data are available before the implementation of the REELEX

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project's solutions and on the other hand whether data covers all of our need for calculating the correspondent KPI.

A specific monitoring plan is going to be defined in future Tasks (T6.1) of the project based on the KPIs needs talking about necessary information for their calculation.

3.4.1 Definition of the baseline period

In order to follow the International Performance Measure and Verification Protocol it is needed to define a baseline period. This period is usually defined previously to the refurbishment works when Energy Conservation Measures (ECM) are going to be installed on a building. In the specific case of the REEFLEX project the EMCs consist of several tools and software services, but also the installation of hardware solutions such as second life batteries. The protocol is very clear regarding the duration of the baseline period and it also depends on the selected option, A, B, C or D for the definition of the mathematical calculations of the ECM to be evaluated. The baseline period must be a representative period of time on which both dependent and independent variables of the mathematical representation of the building / ECM are monitored by a specific hardware (meter) using a determined frequency. Generally, the baseline period for all the KPIs calculated in the REEFLEX project is the time since the project has started until the ECMs (software tools and hardware) will be installed.

3.4.2 Definition of the reporting period

The reporting period is defined on the IPMVP as the period on which savings are going to be evaluated. Regarding the REEFLEX project and the calculation of the KPIs the reporting period starts once the ECMs are deployed on the demo sites of the project. The monitored variables are the same as in the baseline period using the same or equivalent meters and frequency.

3.4.3 Methodology of calculation

In section 2 of this document different entities have been described from a technological perspective. These entities encompass Demo Sites, IPs and UCs. Talking about technologies the more important ones among them are the IPs which are crucial in the development of the project. Therefore, it is essential to evaluate IPs correctly through their specific KPIs. UCs will be evaluated calculating the KPIs of the IPs that compound each UC. How IPs are included in the UCs is shown in the ***Table 2***.

	IP1.1	IP1.2	IO1.3	IP1.4	IP2.1	IP2.2	IP2.3	IP2.4	IP2.5	IP3.1	IP3.2	IP3.3	IP3.4
UC1	X	X	X	X	X			X	X				
UC2	X	X	X	X			X		X	X			
UC3	X	X	X	X		X				X		X	X
UC4	X	X	X	X					X		X	X	X
UC5	X	X	X	X	X	X			X		X	X	X

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UC6	x	x	x	x			x	x	x			x	x
UC7	x	x	x	x	x			x	x	x		x	
UC8	x	x	x	x	x	x		x	x			x	x

Table 2: Innovation Pillars and Use Case distribution

The defined methodology for the Measure and Verification process in the REEFLEX project follows the next steps.

1) Definition of KPIS.
    a. Definition of general KPIs, which are mainly calculated at demo-site level. These KPIs will be the key also to calculate the project impacts.
    b. Analysis of Innovation Pillars and definition of the more accurate KPIs. In this sense, several iterations have been done in order to not to have a very extend list of KPIs. The first version of this list counted with more than 118 values. In the latest iterations was decided that all IPs should have at least one KPI in order to allow the IPs to be evaluated. Hence the number of KPIs was reduced considerably.
    c. Definition of the contingency KPIs, which are defined to be calculated in case some of the defined KPIs can't.
2) Definition of the inputs needed by each of the KPIs. This involves the necessary information to calculate each KPI, for example, energy consumption in a building.
3) Definition of the Monitoring Plan. As mentioned in previous paragraphs, the monitoring plan will be conducted in Task 6.1. feeding this task with the outputs of Task 2.3, which are the definition of the KPIs and the needed inputs.
4) Selection (when it applies) of the IPMVP option for each of the KPIs. The KPIs list contains several KPIs that can be calculated for example by counting, others by a mathematical equation and other maybe will need to be calculated or estimated by the use of a mathematical model. It will also depend on the data available after the definition of the monitoring plan and the possibility to measure all the needed inputs. This activity is done in this first step of the measure and evaluation process but will be reviewed when data are available.
5) Calculation of the KPIs, estimation of savings (when applicable), evaluation of services, comparison between periods. In this phase KPIs are calculated and evaluated in order to ensure our Innovation Pillars are working as expected. Usually, the KPIs related to energy savings will be also compared with the results we would have applying the IPMVP. For the KPIs where IPMVP is not applicable only results of mathematical calculation will be the outputs.

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4 Definition of the Key Performance Indicators

A Key Performance Indicator (KPI) is a specific metric, special measurement tool or calculation that allows to know and evaluate a specific equipment, application or service. In the framework of the REEFLEX project, KPIs will be used to evaluate the technologies that will be applied on the project. In this sense, technologies are divided in two different groups; UCs and IPs (see section 2.2 and section 2.3). In addition to the KPIs referring to these two groups, in order to evaluate general aspects of the project, General KPIs have been defined. Finally, Contingency KPIs will be used in case some of the defined ones for previous aspects (UCs, IPs, and General) cannot be calculated.

4.1 General KPIs

The general KPIs are calculated at the demo site level, independently to a specific Use Case or IP and are defined to cover all the UCs at the same time. These KPIs are extracted from the Project DoA. General KPIs are shown in the following list, note that for each of these KPIs a formulation, description and the desired target are also indicated in the ***Table 3***.

KPI NAME	**GEN1. Enhanced availability of flexibility services.**
FORMULATION	Number of different flexibility services demonstrated within REEFLEX
DESCRIPTION INPUTS	Number of different flexibility services demonstrated within REEFLEX
TARGET	Up to 12 different DSF services
IPMVP OPTION	Option A or B, simple calculation
RELATED UCs	UC1, UC2, UC3, UC4, UC5, UC6, UC7, UC8

KPI NAME	**GEN2. Smartness levels of the grid/consumer groups**
FORMULATION	Weighted average of the scores assigned to different assessment criteria, which are based on data collected through surveys, interviews, or data analysis tools.
DESCRIPTION INPUTS	Implementation of smart appliances able to propose implicit and explicit DR measures and IoT systems for collection and management of main datasets
TARGET	At least level 6 of Smart Readiness Indicator
IPMVP OPTION	Option A or B, simple calculation. Calculation of the SRI.
RELATED UCs	UC1, UC2, UC3, UC4, UC5, UC6, UC7, UC8

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KPI NAME	GEN3. Active participation of consumer groups in DSF markets
FORMULATION	Number of consumers from different sectors (residential, commercial, industrial, e-mobility) that actively participated in DSF markets
DESCRIPTION INPUTS	Number of consumers from different sectors (residential, commercial, industrial, e-mobility) that actively participated in DSF markets
TARGET	> 10.000 consumers engaged within DSF markets
IPMVP OPTION	Option A or B, simple calculation
RELATED UCs	UC1, UC2, UC3, UC4, UC5, UC6, UC7, UC8

KPI NAME	GEN4. Total economic benefits per demo site
FORMULATION	Baseline costs - DSF costs (€/year/(controlled kW))
DESCRIPTION INPUTS	Baseline/DSF energy consumption, applicable energy tariffs
TARGET	>0 (* In the DOA is expected among 10k 20k €, but normalized by kW modifies this target and eases the comparison among demo sites)
IPMVP OPTION	Option A or B, simple calculation. Option C. Simple comparison, as we expect to have all the necessary invoices Option D. When no invoices available for the baseline period.
RELATED UCs	UC1, UC2, UC3, UC4, UC5, UC6, UC7, UC8

KPI NAME	GEN5. Improvement of grid stability, reliability and flexibility
FORMULATION	SAIDI = Total duration of outages / Total number of customers served SAIFI = Total number of outages / Total number of customers served Grid congestion = comparison between total electricity demand/generation and network capacity/operational limits
DESCRIPTION INPUTS	Total duration and number of outages Total number of customers served Total demand of electricity, available capacity of the network Potentially applicable in the Swiss Demo site where the area DSO is in the project but no big impact is expected. This KPI is maintained as complementary to others but it is not basic for the evaluation of the IPs and UCs and could be removed in the future.
TARGET	SAIDI<40 min SAIFI<5 grid congestion<15%

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IPMVP OPTION	Option C. Simple comparison, as we expect to have all the necessary data
RELATED UCs	UC1, UC2, UC3, UC4, UC5, UC6, UC7, UC8

KPI NAME	**GEN 6. Increase RES penetration**
COMMENTS	The increase of RES penetration is not properly expected during the project length, what it is expected is an increase in the Self-consumption (GEN 7), for that reason we will not calculate this KPI, it is replaced by GEN7.

KPI NAME	**GEN7. Self-Consumption Ratio (-)**
FORMULATION	Average daily ratio of the energy consumed from RES to the total energy generated that day for the first year of analysis
DESCRIPTION INPUTS	Data on examined systems energy balance, energy mix and bill of materials (Inputs to be fully detailed for final KPIs to be selected for inclusion in REEFLEX)
TARGET	10%
IPMVP OPTION	Option C. Simple comparison, as we expect to have all the necessary data
RELATED UCs	UC1, UC2, UC3, UC4, UC5, UC6, UC7, UC8

KPI NAME	**GEN 8. Lifetime CO2 Emissions Savings (kg, kg/year or kg/time period)**
FORMULATION	Efficiency of the new installation scenario compared to the existing installation scenario in terms of CO2-eq emissions, during the project's lifetime as well as on annual basis (annual CO2 savings), considering infrastructure and operational costs.
DESCRIPTION INPUTS	CO2 emissions before and after the implementation of the REEFLEX project. Data on examined systems energy balance, energy mix and bill of materials (Inputs to be fully detailed for final KPIs to be selected for inclusion in REEFLEX)
TARGET	Decrease 10%
IPMVP OPTION	Option C. Simple comparison, as we expect to have all the necessary data
RELATED UCs	UC1, UC2, UC3, UC4, UC5, UC6, UC7, UC8

KPI NAME	**GEN9. CO2 Payback Time (CPBT) (years)**
FORMULATION	Number of years required for the new Installation Scenario to recover the infrastructure and operational costs in terms of CO2-eq emissions
DESCRIPTION INPUTS	Data on examined systems energy balance, energy mix and bill of materials (Inputs to be fully detailed for final KPIs to be selected for inclusion in REEFLEX)

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TARGET	10 years
IPMVP OPTION	Option A or B, simple calculation
RELATED UCs	UC1, UC2, UC3, UC4, UC5, UC6, UC7, UC8

KPI NAME	**GEN10. Lifecycle Costs (LCC) (€)**
FORMULATION	Total monetary expenses (capital costs, O&M Costs and fuel costs) for the whole duration of the project.
DESCRIPTION INPUTS	Data on examined systems energy balance, energy mix and bill of materials (Inputs to be fully detailed for final KPIs to be selected for inclusion in REEFLEX)
TARGET	N/A
IPMVP OPTION	Option A or B, simple calculation. Option C. Simple comparison, as we expect to have all the necessary data
RELATED UCs	UC1, UC2, UC3, UC4, UC5, UC6, UC7, UC8

KPI NAME	**GEN11. Lifetime Cost Savings (€/year)**
FORMULATION	Efficiency of the new installation scenario compared to the existing in terms of monetary costs, yearly and during the project's lifetime
DESCRIPTION INPUTS	Data on examined systems energy balance, energy mix and bill of materials (Inputs to be fully detailed for final KPIs to be selected for inclusion in REEFLEX)
TARGET	N/A
IPMVP OPTION	Option A or B, simple calculation. Option C. Simple comparison, as we expect to have all the necessary data
RELATED UCs	UC1, UC2, UC3, UC4, UC5, UC6, UC7, UC8

KPI NAME	**GEN12. Project Performance Index (score: 1-5)**
FORMULATION	This index is being fed by the project success indicators (PSIs) —KPI-like metrics (defined in Impact) which are used to assess the successful (or not) implementation of each project's interventions and their impact against pre-defined targets relevant to this specific project.
DESCRIPTION INPUTS	All PSIs of the project, including specific thresholds/targets
TARGET	Close to 5
IPMVP OPTION	Option A or B, simple calculation
RELATED UCs	UC1, UC2, UC3, UC4, UC5, UC6, UC7, UC8

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KPI NAME	GEN13. Sustainability Impact Index (SII, score: 1-5)
FORMULATION	SII focuses on the multi-dimensional impact that a particular project has to the project sustainable goals of a system and can be extracted on any spatial and temporal scale of interest. The SSI is based on all the KPI defined in a project in contrast to the PPI which incorporates only the (limited in number) PSIs.
DESCRIPTION INPUTS	All KPIs of the project, including specific thresholds/targets
TARGET	Close to 5
IPMVP OPTION	Option A or B, simple calculation
RELATED UCs	UC1, UC2, UC3, UC4, UC5, UC6, UC7, UC8

KPI NAME	GEN14. Sustainability Performance Index (SPI, score: 1-5)
FORMULATION	The SPI aims to provide a cross-dimensional evaluation under four pre-defined overarching sectors - fully aligned with SDGs. Each sector encompasses the most important
DESCRIPTION INPUTS	All KPIs of the project, including specific thresholds/targets and experts' opinions to extract relevant weights per sector
TARGET	Close to 5
IPMVP OPTION	Option A or B, simple calculation
RELATED UCs	UC1, UC2, UC3, UC4, UC5, UC6, UC7, UC8

Table 3: General KPIs definition.

4.2 Specific KPIs for Innovation Pillars

The Innovation Pillars are crucial in the REEFLEX project because they form the technological foundation upon which the project is built. It is very important to know how these technologies are working and their performance. To address this measure, several KPIs have been defined, they are shown in ***Table 4***.

KPI NAME	IP1.1.1 Reduction in data errors
FORMULATION	((Initial number of data errors - Final number of data errors) / Initial number of data errors) * 100
DESCRIPTION INPUTS	Initial number of data errors, final number of data errors
TARGET	Reduce > 95%
RELATED UCs	UC1, UC2, UC3, UC4, UC5, UC6, UC7, UC8
IPMVP OPTION	Option A or B, simple calculation

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KPI NAME	**IP1.2.1. VERIFY's user friendliness**
FORMULATION	Measured in Likert Scale (1-5)
DESCRIPTION INPUTS	User's opinion through relevant questionnaires
TARGET	High - Strongly Agree between 4 and 5 (Very easy to use)
RELATED UCs	UC1, UC2, UC3, UC4, UC5, UC6, UC7, UC8
IPMVP OPTION	Option A or B, simple calculation

KPI NAME	**IP1.2.2. Validated LCA models to be developed**
FORMULATION	Number of LCA models developed
DESCRIPTION INPUTS	Models developed in VERIFY, by capitalizing relevant information to be gathered on technology/demo level
TARGET	4 (one per demo site)
RELATED UCs	UC1, UC2, UC3, UC4, UC5, UC6, UC7, UC8
IPMVP OPTION	Option A or B, simple calculation

KPI NAME	**IP1.3.1. Enhanced decision making and monitoring**
FORMULATION	Measured in Likert Scale (1-5)
DESCRIPTION INPUTS	User's opinion through relevant questionnaires
TARGET	High - Strongly Agree between 4/5 (Platform significantly helps decision making)
RELATED UCs	UC1, UC2, UC3, UC4, UC5, UC6, UC7, UC8
IPMVP OPTION	Option A or B, simple calculation

KPI NAME	**IP1.3.2. Upgrade USE KPI repository**
FORMULATION	Number of new KPIs to be included in USE KPI repository
DESCRIPTION INPUTS	USE will adopt several of REEFLEX KPIs to upgrade its database and perform the necessary estimations
TARGET	At least 20

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RELATED UCs	UC1, UC2, UC3, UC4, UC5, UC6, UC7, UC8
IPMVP OPTION	Option A or B, simple calculation

KPI NAME	**IP1.4.1. Flexibility and DR categorization tool**
FORMULATION	Number of energy smart home appliances classified and included in the catalogue
DESCRIPTION INPUTS	Data on the total number of energy smart home appliances in the market, data on the number of energy smart home appliances classified and included in the catalogue
TARGET	>50 devices included in the catalogue
RELATED UCs	UC1, UC3, UC8
IPMVP OPTION	Option A or B, simple calculation

KPI NAME	**IP2.1.1 GHG emissions saved compared to equivalent new batteries [%]**
FORMULATION	[(GHG 2nd life batt - GHG new batt)/GHG new batt)]*100
DESCRIPTION INPUTS	Analysis of GHG emissions of 2nd life and new batteries
TARGET	>10%
RELATED UCs	UC1, UC5, UC7, UC8
IPMVP OPTION	Option A or B, simple calculation. Option C. Simple comparison, as we expect to have all the necessary data

KPI NAME	**IP2.1.2. Cost per kWh Stored**
FORMULATION	Battery Cost / Cost per kWh Stored
DESCRIPTION INPUTS	Cost Of the battery / stored energy / injected energy
TARGET	Reduce by 5%
RELATED UCs	UC1, UC5, UC7, UC8
IPMVP OPTION	Option A or B, simple calculation. Option C. Simple comparison, as we expect to have all the necessary data

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KPI NAME	**IP2.2.1. Smart home solutions to control home appliances**
FORMULATION	[(New devices that potentially could provide flexibility installed in demos-New devices installed in demos)/New devices installed in demos)]*100
DESCRIPTION INPUTS	Number of new devices installed in demos and its characteristics
TARGET	>10%
RELATED UCs	UC3, UC5, UC8
IPMVP OPTION	Option A or B, simple calculation. Option C. Simple comparison, as we expect to have all the necessary data

KPI NAME	**IP2.3.1 Error in the power of every disaggregated demand (component) and in the total demand**
FORMULATION	NRMSE (or others as MAE or MRE)
DESCRIPTION INPUTS	NILM outputs
TARGET	Close to zero
RELATED UCs	UC2, UC6
IPMVP OPTION	Option A or B, simple calculation. Option C. Simple comparison, as we expect to have all the necessary data

KPI NAME	**IP2.4.1. Converter (charging/discharging) efficiency at different working regimes**
FORMULATION	(Output power - Input power)/ input power
DESCRIPTION INPUTS	Operation data (Input/output data)
TARGET	>85%
RELATED UCs	UC1, UC6, UC7, UC8
IPMVP OPTION	Option A or B, simple calculation. Option C. Simple comparison, as we expect to have all the necessary data

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KPI NAME	**IP2.4.2. Precision following different P & Q set-points for independent battery packs**
FORMULATION	NRMSE (or others as MAE or MRE)
DESCRIPTION INPUTS	Operation setpoints, System operation data
TARGET	<10% error for different battery setpoints (in permanent)
RELATED UCs	UC1, UC6, UC7, UC8
IPMVP OPTION	Option A or B, simple calculation.

KPI NAME	**IP2.5.1. (Average) Ratio of daily flexible energy over expected consumption, in the long term**
FORMULATION	Average_flexible_energy / total_consumption
DESCRIPTION INPUTS	Forecasted consumption + forecasted flexibility, of asset or building
TARGET	>10%
RELATED UCs	UC1, UC2, UC4, UC5, UC6, UC7, UC8
IPMVP OPTION	Option A or B, simple calculation. Option C. Simple comparison, as we expect to have all the necessary data

KPI NAME	**IP2.5.2. Success rate of Demand-Response events - flexibility activation signals during testing**
FORMULATION	Number of successful DR events over total number of DR events
DESCRIPTION INPUTS	Log data about flexibility activation signals between REEFLEX platform and trading platform + between REEFLEX platform and prosumers.
TARGET	>10%
RELATED UCs	UC1, UC2, UC4, UC5, UC6, UC7, UC8
IPMVP OPTION	Option A or B, simple calculation.

KPI NAME	**IP2.5.3 (Average) cost reduction (of consumption costs) by optimally trading flexibility (e.g. of data centres) in energy markets and ancillary services.**
FORMULATION	(Initial Cost – Reduced Cost) / Initial Cost, per building or asset or EV
DESCRIPTION INPUTS	Flexibility market real-time prices + baseline consumption of asset (or EV) (before optimisation) + flexibility of asset or EV + optimised consumption
TARGET	>10%

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RELATED UCs	UC1, UC2, UC4, UC5, UC6, UC7, UC8
IPMVP OPTION	Option A or B, simple calculation. Option C. Simple comparison, as we expect to have all the necessary data

KPI NAME	**IP2.5.4 Ability for load reduction (in kW kWh) per vehicle in different charging sites for peak shaving.**
FORMULATION	(Consumed power before_optimisation - Consumed power after_optimisation) / Consumed power before_optimisation , in peak hours, per EV
DESCRIPTION INPUTS	Charging schedule per EV, flexibility market real-time prices (if the peak shaving is done via pricing mechanism), or DR signals and rewards if it is done via a rewarding mechanism
TARGET	>10%
RELATED UCs	UC1, UC2, UC4, UC5, UC6, UC7, UC8
IPMVP OPTION	Option A or B, simple calculation. Option C. Simple comparison, as we expect to have all the necessary data

KPI NAME	**IP2.5.5. Cost savings for consumer(s) [%]**
FORMULATION	[((daily energy cost using optimised setpoints) - (daily energy cost BaU))/ (daily energy cost BaU)]*100
DESCRIPTION INPUTS	Daily energy cost using optimised setpoints and daily energy cost BaU (without optimization)
TARGET	At least >5%
RELATED UCs	UC1, UC2, UC4, UC5, UC6, UC7, UC8
IPMPV OPTION	Option A or B, simple calculation. Option C. Simple comparison, as we expect to have all the necessary data

KPI NAME	**IP2.5.6. Success rate optimising user operation [%]**
FORMULATION	[number of module uses that provides optimised results/number of module uses]*100
DESCRIPTION INPUTS	Number of module uses that provides optimised results and number of module uses
TARGET	>75%
RELATED UCs	UC1, UC2, UC4, UC5, UC6, UC7, UC8
IPMPV OPTION	Option A or B, simple calculation.

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KPI NAME	**IP2.5.7 Average cost reduction of consumption costs by optimally trading flexibility In energy markets and ancillary services.**
FORMULATION	(Initial Cost – Reduced Cost) / Initial Cost, per building or asset or EV
DESCRIPTION INPUTS	Flexibility market real-time prices + baseline consumption of asset (or EV) (before optimisation) + flexibility of asset or EV + optimised consumption
TARGET	>10%
RELATED UCs	UC1, UC2, UC4, UC5, UC6, UC7, UC8
IPMPV OPTION	Option A or B, simple calculation. Option C. Simple comparison, as we expect to have all the necessary data

KPI NAME	**IP3.1.1. Flex hours per day and user [%]**
FORMULATION	[number of hours with flexibility possibilities to be traded in FM/24]*100
DESCRIPTION INPUTS	Number of hours with flexibility possibilities to be traded in FM
TARGET	>10%
RELATED UCs	UC2, UC3, UC7
IPMPV OPTION	Option A or B, simple calculation. Option C. Simple comparison, as we expect to have all the necessary data

KPI NAME	**IP3.1.2. Success rate calculating flex [%]**
FORMULATION	[number of flex calculation module uses that provides flexibility/number of flex calculation module uses]*100
DESCRIPTION INPUTS	Number of flex calculation module uses that provides flexibility and number of flex calculation module uses
TARGET	>75%
RELATED UCs	UC2, UC3, UC7
IPMPV OPTION	Option A or B, simple calculation. Option C. Simple comparison, as we expect to have all the necessary data

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KPI NAME	IP3.1.3. Success rate aggregating flex [%]
FORMULATION	[number of flex aggregation module uses that provides results/number of flex aggregation module uses]*100
DESCRIPTION INPUTS	Number of flex aggregation module uses that provides results and number of flex aggregation module uses
TARGET	>90%
RELATED UCs	UC2, UC3, UC7
IPMPV OPTION	Option A or B, simple calculation. Option C. Simple comparison, as we expect to have all the necessary data

KPI NAME	IP3.1.4 Increased system flexibility for energy players
FORMULATION	(New system flexibility – previous flexibility) *100 / previous flexibility
DESCRIPTION INPUTS	Amount of load capacity participating in demand side management [W], Ppeak. The indicator determines the increased system flexibility for the energy utilities as an effective way to exploit all resources to respond to a set of diversions (e.g., demand changes in a specific time interval) and maintain the power balance, in terms of load or cost.
TARGET	>10%
RELATED UCs	UC4
IPMPV OPTION	Option A or B, simple calculation. Option C. Simple comparison, as we expect to have all the necessary data

KPI NAME	IP3.1.5 Short-term flexibility utilization rate
FORMULATION	Short-term flexibility utilization rate = (Actual utilization of short-term flexibility) / (Total reserved short-term flexibility)
DESCRIPTION INPUTS	Current utilization of short-term flexibility and Total reserved short-term flexibility
TARGET	>0.3
RELATED UCs	UC5
IPMPV OPTION	Option A or B, simple calculation. Option C. Simple comparison, as we expect to have all the necessary data

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KPI NAME	IP3.2.1. Error in the location of congested lines
FORMULATION	{[Forecasted congested lines - Real congested lines]/Real congested lines} *100 average per line
DESCRIPTION INPUTS	Based on the estimated load profile (baseline), the lines that could be overloaded will be identified. Subsequently, the lines that were overloaded or would be overloaded without the flexibility actions will be compared. The metric considers an identification to be correct when the line identifier matches in both the baseline and the regular operation."
TARGET	As close to 0 as possible
RELATED UCs	UC4, UC5
IPMPV OPTION	Option A or B, simple calculation. Option C. Simple comparison, as we expect to have all the necessary data

KPI NAME	IP3.2.2. Flexibility needs covered in the market
FORMULATION	(Flexibility needs issues-Flexibility needs covered in the market) /Flexibility needs issues
DESCRIPTION INPUTS	Flexibility needs issues and Flexibility needs covered in the market
TARGET	>0.7
RELATED UCs	UC4, UC5
IPMPV OPTION	Option A or B, simple calculation. Option C. Simple comparison, as we expect to have all the necessary data

KPI NAME	IP3.2.3. Error of flexibility needs forecast (%)
FORMULATION	{[Forecasted flexibility needs (MW) - Real flexibility needs (MW)]/Real flexibility needs (MW)}*100
DESCRIPTION INPUTS	Forecasted and real flexibility needs in MW
TARGET	As close to 0 as possible
RELATED UCs	UC4, UC5
IPMPV OPTION	Option A or B, simple calculation. Option C. Simple comparison, as we expect to have all the necessary data

KPI NAME	IP3.3.1 Accuracy of short-term reserve market prediction
FORMULATION	Mean absolute percentage error (MAPE)

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DESCRIPTION INPUTS	Actual and predicted reserve market characteristics (e.g. price, quantity) for a given time period
TARGET	MAPE < 5%
RELATED UCs	UC4, UC5, UC6, UC7, UC8
IPMPV OPTION	Option A or B, simple calculation.

KPI NAME	**IP3.3.2 Intraday market revenue, Short-term market revenue (portfolio level/per participant)**
FORMULATION	Short-term market revenue = Total revenue earned from participating in short-term energy market
DESCRIPTION INPUTS	Flexibility offered in short-term markets, tariff/compensation fee
TARGET	N/A
RELATED UCs	UC5
IPMPV OPTION	Option A or B, simple calculation.

KPI NAME	**IP3.4.1. Success rate matching generators and consumers [%]**
FORMULATION	[number of P2P module uses that provides results/number of P2P module uses]*100
DESCRIPTION INPUTS	Actual number of P2P module uses that provides results and number of P2P module uses
TARGET	>70%
RELATED UCs	
IPMVP OPTION	Option A or B, simple calculation.

Table 4: Innovation Pillars KPIs.

4.3 Contingency KPIs

The contingency KPIs will be calculated when no data or any other constraint does not allow the calculation of the previous KPIs and when available calculated KPI are not considered as representative enough for the evaluation of the developments of the project. They have been defined as simple as possible to make them calculable with the minimum data. The contingency KPIs are shown in the ***Table 5***.

KPI NAME	**CON01. Efficiency of Total Energy**
FORMULATION	(Consumed energy / Total primary energy consumed) * 100

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DESCRIPTION INPUTS	Consumed energy, Total primary energy consumed. Measures the overall efficiency of the platform in converting primary energy into used energy.
TARGET	>10%
RELATED UCs	UC1, UC2, UC3, UC4, UC5, UC6, UC7, UC8
IPMVP OPTION	Option C

KPI NAME	**CON02. Proportion of Renewable Energy**
FORMULATION	(Renewable energy used / Total energy consumed) * 100
DESCRIPTION INPUTS	Renewable energy used; Total energy consumed. Evaluates the proportion of consumed energy derived from renewable sources.
TARGET	>10%
RELATED UCs	UC1, UC2, UC3, UC4, UC5, UC6, UC7, UC8
IPMVP OPTION	Option C

KPI NAME	**CON03. Avoided CO2 Emissions**
FORMULATION	(Estimated emissions before REEFLEX implementation - Actual emissions after REEFLEX implementation)
DESCRIPTION INPUTS	Estimated emissions without the platform, Actual emissions with the platform. Quantifies the estimated reduction in CO2 emissions due to the platform's participation.
TARGET	>10%
RELATED UCs	UC1, UC2, UC3, UC4, UC5, UC6, UC7, UC8
IPMVP OPTION	Option C

KPI NAME	**CON04. Demand Management Efficiency**
FORMULATION	(Achieved demand reduction / Previous demand (in the baseline period)) * 100
DESCRIPTION INPUTS	Achieved demand reduction, Total previous demand. Measures the effectiveness of the platform in managing and reducing energy demand.
TARGET	>10%
RELATED UCs	UC1, UC2, UC3, UC4, UC5, UC6, UC7, UC8
IPMVP OPTION	Option C

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KPI NAME	CON05. Effectiveness in Reducing Energy Losses
FORMULATION	(Delivered useful energy / Total generated energy) * 100
DESCRIPTION INPUTS	Delivered useful energy, Total generated energy. Measures the platform's efficiency in minimizing energy losses during generation and delivery.
TARGET	>5%
RELATED UCs	UC1, UC2, UC3, UC4, UC5, UC6, UC7, UC8
IPMVP OPTION	Option C

KPI NAME	CON06. Total Energy Savings
FORMULATION	Total energy saved thanks to the REEFLEX project
DESCRIPTION INPUTS	Total energy consumed before and after the REEFLEX implementation. Quantifies the overall amount of energy saved due to the implementation of the platform.
TARGET	>15%
RELATED UCs	UC1, UC2, UC3, UC4, UC5, UC6, UC7, UC8
IPMVP OPTION	Option C

Table 5: Contingency KPIs

4.4 Implementation and monitoring

4.4.1 Data source for each Demo Site and Use Case

As mentioned in other sections the monitoring plan will be developed and carried out in the WP6. Specific task will be conducted to define the equipment necessary to install (in case it is not already installed) for each demo-site (T6.1). T6.2, T6.3, T6.4 and 6.5 will perform the installation of all necessary elements.

As the basis of the monitoring plan the description inputs from ***Table 3***, ***Table 4*** and ***Table 5*** will be considered. Not only is it crucial to define what needs to be measured through Key Performance Indicators (KPIs), but it is equally important to consider the characteristics of meters or sensors, where applicable. Characteristics such as resolution, precision, and uncertainty play a vital role in ensuring the accuracy and reliability of measurements. Therefore, when establishing a monitoring plan, it is imperative to carefully assess and document the technical specifications of the instruments used. This includes understanding the resolution capabilities, precision level, and uncertainty associated with the meters or sensors employed in the data collection process. The IPMVP defines clearly how to play with data taking into consideration these characteristics.

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5 Competitors analysis

In this section, a short comparison with competitors is done for each of the Innovation Pillars of the project. Note that in this section a light comparison of the project solutions with other solutions in the market is done. Lately in the project, in the exploitation related activities a more detailed analysis will be provided.

5.1 Innovation Pillar 1. Interoperability and data exchange platform.

5.1.1 IP1.1. REEFLEX Platform: data exchange, handling and interoperability.

The core Data Platform of REEFLEX consist of the data space environment: thus, different modules are considered to set the overall solution. At first, the data governance mechanisms and components that allow for the effective handling and processing of the data available in the physical world. In more detail the Data Platform of REEFLEX incorporates the required data harvesting and ingestion methods to facilitate the effortless uploading of batch data as files, the collection of data via 3rd-party APIs and the ingestion of streaming data through available PubSub mechanisms (MQTT, Kafka). Moreover, appropriate data mapping mechanisms are considered to allow the harmonization of available datasets to the REEFLEX Data Model, while a configuration environment will be offered to the platform’s users so that they can effectively define the cleaning rules for handling any incorrect, incomplete, inaccurate, irrelevant or missing parts of the data. Moreover, a sovereign framework around prosumers’ data is provided by allowing them to define custom rules for the handling of their data (based on their own preferences) while ensuring that they always are in control and can effectively monitor the way their data are treated and used by other stakeholders. Additionally, the Data Platform of REEFLEX incorporates the data exploration mechanisms that will enable visual exploration of data assets uploaded and ingested in the Data Platform thus enabling end-users to search for and discover the datasets of their interest for further use in business applications residing on top of the Data Platform. Subsequently, the Data Platform of REEFLEX supports the implementation of the data retrieval service to enable retrieval of selected data sets, through dynamically configured APIs based on the querying parameters defined by the end users.

BSoA: Below the key competitive advantages – REEFLEX Data Platform against other software tools that are aiming to set a data space environment:

1. REEFLEX Data Platform incorporates different standards-based ingestion methods to ensure connectivity with different data sources in the energy sector
2. REEFLEX Data Platform semantic interoperability through the definition of the REEFLEX Data Model that can be dynamically configured and easily maintained to address different UCs and data management needs
3. REEFLEX Data Platform enhanced support on privacy and security over the data handled in the platform

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REEFLEX Data Platform advanced data exploration functionality to ensure easy access to the data available in the data space environment.

REEFLEX Data Platform customization to address different UCs and business needs of the actors

The Competition Matrix for REEFLEX Data Platform has been developed considering tools that can potentially serve a similar goal. The analysis is covering solutions from domain specific vendors.

Technical characteristics	Atos Smart Grid Suite	Siemens IPEnergy	Schneider EcoStruxure	REEFLEX
Standards-based ingestion	✓	✓	✓	✓
Semantic interoperability based on a common, standards-based data model	✓	✓	Partially	✓
Enhanced support on privacy and security	✓	✓	✓	✓
Advanced data exploration	✓	✓	✓	✓
Customization to different needs	Partially	Partially	Partially	✓

Table 6: Competition matrix for IP1.1.

5.1.2 IP1.2. VERIFY: Web based platform enabling LCA and LCC of projects (Life Cycle Assessment and Life Cycle Cost).

There are several software tools available that can conduct LCAs of energy systems. Some commonly indicative used software tools for energy system LCA include SimaPro, GaBi, OpenLCA, eTool, CES EduPack. This list is not exhaustive, and there are other LCA software tools available as well. The choice of software tool depends on the specific requirements of the energy system being assessed, the level of detail needed, and the available data and resources. LCA tools vary in their features, data requirements, cost, and user-friendliness, while some require specialized expertise to use, compared to others. The table below lists LCA tools that require an intermediate or an advanced level of expertise.

LCA Tools requiring an intermediate level of expertise	LEGEP, EQUER, ATHENA, ENVEST 2.0, BEES, GREENCALC, ECOEFFECT, ECO-SOFT, oneclicklca
LCA tools requiring an advanced level of expertise	BOUSTEAD, ECO-IT, ECOPRO, EUKLID, GABI, MIET, SIMAPRO, TEAM, UMBERTO, Openlca, Mobius

Table 7: LCA Tools requiring an intermediate or advanced level of expertise.

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BSoA: More extensive experience is required to handle more advanced LCA applications. These tools require a lot of training and a deep understanding of LCA models and may not be suitable for applications in early design phases. VERIFY can be categorized as a tool requiring minimum expertise since most of the data is retrieved automatically from relevant databases and IoT devices. Below the key competitive advantages – selling points of VERIFY against other LCA tools are summarized:

Dynamic LCA/LCC analysis: Accountability for real-time (real-life) data and not only by estimations - offers tailored suggestions and visualization for energy, environmental, and financial sustainability by delivering automated dynamic life cycle and life costing analyses of energy systems/technologies in real time;

Hybrid LCA/LCC capabilities: It offers trustworthy and accurate LCC functionality in addition to LCA capability, which supports an investment planning tool for giving important information to decision- and policymakers in a single online tool;

Enhanced accuracy: An online data preparation and storing engine solves common issues like missing data or corrupt databases.

Multi-purpose: VERIFY serves studies at different levels i.e., technology, buildings up to districts;

Cost savings: Competitive price over competition;

Time savings: Automated data import of energy profiles from linked energy software (INTEMA). No need to conduct full inventory analysis - LCI for multiple technologies is already included. In the case of building level estimations, the automation, except from real-time data ingestions from multiple active and passive energy systems, across multiple vectors, also including the case of Power-to-X integrated systems, is based on the use of Building Information Modeling (BIM), and it involves energy, environmental, and techno-economic data aimed at the multi-criteria evaluation of several scenarios for the design of a new building energy system or the upgrading of an existing one;

Enhanced interoperability: It is a fully open-source and interoperable software i.e., external APIs can be connected to the VERIFY platform, to receive data automatically in real time through communication channels (e.g., Action Cable and MQTT protocol);

User-friendly even to non-experts: It offers a user-friendly interface and navigation, offering a drag-and-drop interface for building life cycle models and direct visualization of the results;

No installation required: VERIFY is a web-based application accessible through any PC.

The VERIFY competition matrix below includes selected competitive tools for the building sector, which is a core market for VERIFY and LCA studies.

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Technical characteristics	One Click	BEES Online	Ecocalculator Athena	VERIFY
Integrated LCA for carbon footprint, LCC and Investment Planning approach	Partially	Partially	Partially	✓
Dynamic LCA/LCC analysis using real time data	X	X	X	✓
Interoperability	✓	X	X	✓
User friendliness (GUI)	✓	X	X	✓
Web interface	✓	X	X	✓

Table 8: Competition matrix for IP1.2.

5.1.3 IP1.3. USE: Platform enabling uniform evaluation of projects.

There are only a few software programs available that can perform impact evaluations of smart city interventions. Some of those software solutions are briefly presented below.

UrbanSim: This is a land-use and transportation simulation model developed by the University of California, Berkeley. It can be used to evaluate the impacts of a wide range of urban interventions, including changes to transportation infrastructure, zoning regulations, and building codes;

SAT4SUD (indirect competitor): The Self-Assessment Tool for Sustainable Urban Development strategies is designed for Local Authorities and national and regional Managing Authorities of EU Cohesion. The tool focuses at promoting self-assessment as an important learning practice to critically reflect on the strategy, recognize strengths and identify opportunities for improvement;

OECD Urban Principles toolkit (under development) (indirect competitor): The tool will aim to provide guidance to local and national governments in implementing the OECD Principles on Urban Policy. It will support both cities and countries in assessing and benchmarking their urban policies within a holistic framework and build on good practices across OECD countries;

Measuring the distance to the SDGs in regions and cities (indirect competitor): The OECD has developed a visualization web tool to help policymakers measure the distance of regions and cities towards the SDGs. The tool covers around 600 regions and 600 cities from OECD and partner countries and includes more than 100 indicators to monitor progress across the 17 SDGs. These indicators can be visualized individually or as a composite index;

Green City Tool (not accessible): Working both as a means of benchmarking and as a self-assessment, the Green City tool developed by the European Commission allows cities to commit and communicate their efforts to becoming greener and more sustainable. With a focus on sustainable urban planning, the tool emphasizes on city governance and approach, rather than quantitative measures;

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SCM Self-Reporting Tool. The SRT is a tool for project coordinators to report on projects' relevant outputs and information and populate the Smart City Marketplace database. SRT users (project coordinators, for example), will use this tool to upload the relevant information on the different interventions carried out on in smart city projects i.e., new and refurbished buildings, energy supply units as well as mobility and ICT actions.

BSoA: Below the key competitive advantages – selling points of USE against other software tools that are aiming at the holistic sustainability assessment of anthropogenic activities are summarized:

- USE can be tailored to incorporate several technological, environmental, economic, and social criteria, producing simple indicators, after aggregating KPIs appropriately both terms of space (e.g., positive energy building, positive energy district, city) dimension (economic, energy, environmental, governance, ICT, mobility, propagation, social) and sector (climate change and mitigation, Quality of life and prosperity, resource efficiency, smart and reliable infrastructure).
- USE can be used to benchmark the success of smart city (or relevant) interventions against any pre-defined goals.
- USE can be used to benchmark the contribution of smart city (or relevant) interventions to the national and/or international key objectives i.e., SDG goals.
- USE can be used to compare the impact of different smart cities (or relevant) interventions and guide decision making on prioritizing investments and assist policy making.
- USE is supported by an easy-to-navigate graphical user interface which is suitable also for non-experts. It uses clear jargon-free language, provides visual aids and clear instruction and help documentation.

The Competition Matrix for USE has been developed considering tools that can potentially serve a similar goal.

Technical Characteristics	UrbanSim	SCM Self-Reporting Tool	Distance to SDGs	USE
Self-populated KPIs	X	X	X	✓
Comparison of multiple projects	✓	✓	X	✓
Comparison of multiple cities	X	X	✓	✓
Case-specific Importance of indicators	X	X	X	✓

Table 9: Competition matrix for IP1.3.

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5.1.4 IP1.4. Flexibility potential classification for any given asset.

The objective of a tool able to classify "flexibility potential for any given asset" that can be used to provide flexibility in different environments (residential or commercial for example) is to generate a flexibility potential evaluation methodology and create and populate a catalogue of these devices. This tool and the generated catalogue will have two potential uses: (i) it will allow choosing devices for the home so that the consumer/prosumer can offer greater flexibility in different markets, and (ii) it will allow understanding the flexibility potential of a provider in a standardized way.

BSoA: Creating algorithms for classifying and orchestrating the flexibility potential of assets and end-users will enable a uniform and rapid understanding of the characteristics of any flexible resource. This, in turn, facilitates the seamless integration and utilization of these resources in flexibility markets. Such advancements will streamline the onboarding of new customers or players looking to modernize their installations.

The project's proposed work will start from SRI calculation (Smart Readiness Indicator), a metric currently applied to buildings and building units. While some scientific efforts have aimed to expand the SRI for quantitatively assessing a building's load-shifting potential, the most promising proposal for evolution or improvement in practical use comes from APPLiA, focusing on enhancing Demand-Side Flexibility (DSF). REEFLEX aims to extend and enhance the SRI concept by adapting it to devices that contribute to flexibility in the following ways:

- classifying these devices based on their characteristics to enhance system flexibility;
- creating, populating, and continually updating a collectively agreed-upon catalogue of energy-smart home appliances;
- developing a protocol for every manageable element to provide a basic description from a flexibility standpoint;
- creating a flexibility classification algorithm.

The SRI assesses static characteristics, and the proposed tool in this project aims to evaluate the flexibility potential of different assets in various scenarios. This is because the same device may not generate the same flexibility possibilities in different environments, uses, or geographical regions. So far, no commercial tools with similar functionalities have been found, so a comparison with them cannot be made. There are scientific papers proposing methodologies to evaluate the flexibility of assets, but these are focused on assessing large electrical systems or flexibility in specific contexts. In contrast, the solution to be developed in the project aims to evaluate static characteristics and other dynamics in different scenarios, representing an evolution from current state-of-the-art proposals.

Competition: Now, there are no identified competitors that provide commercial products or methodologies that evaluate flexibility potential of different assets. A state-of-the-art review has shown that most similar efforts focus on assessing the flexibility of complex systems and not just elements: VPPs, power systems, consumers, renewable generation plants, etc…

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5.2 Innovation Pillar 2. Optimal management and flexibility potential.

5.2.1 IP2.1. Second-life batteries as flexibility assets.

The 2nd life battery energy storage system consists of various sub-systems. The **automotive battery** which will be repurposed on module level to reach a technoeconomic balance between repurposing effort and remaining lifetime - where the repurposing will not be limited to the battery modules itself but also contain BMS, contactor, fusing and cabling where possible.

The core of this development will be the **universal battery management system (BETT's BMU).** Since 2nd-life often comes with low quantities and unstable incoming supply flows the controller needs to be as flexible towards the battery side as possible. On the other hand, it shall ensure a stable and standardized interface towards external controllers like smart inverters, energy management systems and site controllers.

This leads to a modular software approach with different layers and an approach of allowing **two different operation modes**. In the **system BMS operation mode** the BMU will only act as a system BMS for the battery DC system - taking care of safety aspects on battery side, parallelizing battery packs, etc. and leave the overall system control to a third-party controller or a smart inverter. In the **full BESS control mode** the BMU will also take care of other subsystems of the overall battery energy storage system like inverters, HVAC and devices on the AC side.

To allow for a flexible use towards different subsystem suppliers the BMU architecture has different software layers. A core **battery energy storage system layer** taking care of the overall system control, an **objectified subsystem layer** for battery, power electronics, HVAC and a dedicated **vendor layer** forming the flexible interface to specific BMS or inverters.

This universal battery management system at the same time ensures optimized operation for specific battery characteristics (chemistry, etc.) by pushing data to a higher-level cloud that allows for analysis by means of AI and then may give feedback to the universal battery management system in regards of preferred operation limits.

The battery system can be modular increased by **30 kWh / 15 kW building blocks to up to 240 kWh** with the current battery batch but also allows for higher capacity building blocks with newer generation 2nd-life or 1st life modules.

BSoA: Since the REEFLEX development is only a subsystem of a product BETT is looking to develop, it is hard to define differentiating points from competitors.

The few 2nd-life suppliers that currently exist on the market, act mostly as subsystem suppliers, same as BETT will do in REEFLEX. In the end, BETT aims to be a system integrator for 2nd-life battery solutions which means also offering application integration logic and integration of other subsystems. This combined with an exceptional knowledge in battery aging and characterization allows for optimized operation and thus likely also is the biggest differentiator.

As well the very flexible design of our BMU allows for a highly versatile usage of the battery system.

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Technical Characteristics	Stabl	Voltfang	Evyon	Connected Energy	betteries
BMU as 2nd life optimized system controller	X	X	X	✓	✓
Reuse more than just battery cells	X	X	X	✓	✓
Battery analytics	✓	✓	✓	✓	✓
Architecture agnostic to battery side	✓	X	X	X	✓

Table 10: Competition matrix for IP2.1.

5.2.2 IP2.2. Predictive flexibility potential and operation of distributed devices.

Description: Devices with connectivity capability has numerous potentials for flexibility of power distribution. They can inform grid controller or aggregator about current situation, future request and capabilities. For example, a smart plus may have on/off capability, informing voltage-current-instant power capability. By supplying this capability, it gives control of connected device power consumption. Grid or aggregator has information about consumed instant power on this specific device. As another example a refrigerator may supply info about current temperature and current power consumption. By changing temperature value, it gives capability to arrange consumed power. Some devices like washer and dishwasher has capability of postponing its working and remote start. By this capability grid controller has play-pause control on these devices to arrange load on selected area.

Connected devices may have capability of informing grid about its capabilities, device info and functions.

There should be a standard data model and service info to share this info about devices and grid. In this project one the of aims is to create data model and services to share this information.

BSoA: There are some standards about standardization of devices and services for sharing. In this project aim is create a simpler and effective data model and services structure to ease implementation. Search for common ways to run different gateway for various peripheral devices and help them to talk with grid services.

5.2.3 IP2.3. Non-Intrusive Load Monitoring (NILM) techniques for large consumers' load disaggregation

The residential non-intrusive load monitoring (NILM) algorithm is an important part of the REEFLEX platform and contributes to the optimal management of the available resources. Its

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goal is to distinguish electrical loads (appliances), by examining only the aggregated power consumption of a building. In the context of the REEFLEX project this information will be used for enhancing the monitoring services provided to the end-users as well as for improving the calculation of flexible energy of residential buildings.

BSoA: While residential NILM, or residential disaggregation, is a service offered by various organizations at both research and commercial levels, the approach presented within the REEFLEX project brings forth several noteworthy advantages. Specifically, the algorithms that are developed are able to operate on variable granularity, that is the time resolution is configurable. Moreover, the proposed solution can be customized on the characteristics of different scenarios, considering additional information related to the model of appliances or the historical internal and external temperature data of residential buildings etc. Finally, the residential NILM algorithm that is developed in the context of REEFLEX is designed to allow continuous improvement of the artificial intelligence algorithms according to most recent advancements in load monitoring technology.

Technical Characteristics	Sense	Neurio	Bidgely	REEFLEX residential NILM
Real-time monitoring	✓	✓	X	✓
Customization and personalization	X	X	✓	✓

Table 11: Competition matrix for IP2.3

Non-Intrusive Load Monitoring (NILM) techniques play a pivotal role in industrial environments. By deploying NILM techniques, large consumers in industrial settings can seamlessly participate in flexibility markets. These techniques enable the identification of flexible energy sources within complex and dynamic industrial facilities, overcoming challenges posed by diverse energy-consuming systems and variable-speed drives. With the ability to disaggregate energy usage and provide tailored flexibility recommendations, NILM not only reduces the impact of interventions on consumers but also minimizes costs, fostering greater engagement in flexibility markets. The integration of Industry 4.0 concepts further enhances the adaptability and accuracy of NILM techniques, making them instrumental in optimizing energy management for industrial consumers.

BSoA: REEFLEX introduces a pioneering innovation by extending Non-Intrusive Load Monitoring (NILM) techniques from domestic to industrial applications. This ground-breaking approach identifies flexible energy sources within complex industrial environments, addressing challenges posed by diverse energy-consuming systems and dynamic variables. By integrating Industry 4.0 principles, REEFLEX enhances NILM with data from production processes, external influencers, and energy metering, providing a robust foundation for Machine Learning (ML) and Deep Learning (DL) algorithms. The result is a comprehensive framework capable of disaggregating various energy loads in industrial settings, easing the participation of large consumers in flexibility markets while minimizing costs and optimizing energy management.

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Competition: Currently, there are no identified competitors that provides commercial services related to NILM techniques for industrial environments (TRL 5). A state-of-the-art review indicates that research is focused on overcoming barriers associated with assumptions often made in residential NILM developments, such as steady-state loads, one-at-a-time assumptions, and the increase in the number of dynamic loads to disaggregate in industrial cases which may require more robust algorithms and computational capabilities to generate accurate models.

5.2.4 IP2.4. Innovative inverters for storage systems and electric vehicles (V2G)

In the imminent future of the electric system, the pivotal role of innovative inverters for storage systems and electric vehicles (V2G) becomes increasingly evident. As the demand for electric vehicles surges, the need for efficient, grid-responsive charging solutions is paramount. Innovative inverters not only tackle the existing challenges of prolonged charging times and high electricity costs but also empower the electric system to adapt to evolving patterns of renewable energy integration and distributed resources.

These cutting-edge inverters, designed with smart grid applications in mind, transcend the limitations of traditional systems. They support bidirectional power flow, ensuring seamless energy exchange between the grid and storage systems or V2G-enabled electric vehicles. Their ability to operate under unbalanced loads and provide ancillary services aligns perfectly with the dynamic nature of renewable energy sources. Importantly, these inverters offer crucial support to Distribution System Operators (DSOs), enhancing grid stability, flexibility, and resilience. In essence, these innovations mark a transformative step towards a more sustainable and responsive electric ecosystem.

BSoA: REEFLEX introduces an innovative inverter for storage systems and electric vehicles (V2G), addressing limitations in current market solutions. The modular configuration allows scalable adaptation to diverse power requirements, with 25-kW AC/DC and DC/DC bidirectional modules. Unlike existing solutions, the high-frequency galvanic isolation ensures safe operation, while SiC technology optimizes efficiency and size. Another advantage is its capability of a high variety of output voltages, ranging from 150 to 1000V. These modules can provide ancillary services to the grid, addressing unbalanced grids, power factor regulation, and voltage regulation, surpassing the capabilities of conventional solutions. Importantly, this innovation extends beyond BESS to include PV and EV charging systems, filling critical gaps in the current market offerings.

The advantages against the commercial alternatives are:

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Technical Characteristics	TIB3850M100NK	RedPrime 25kW	BEG1K075G	REEFLEX optimal grid management algorithms
Complex ancillary services.	✓	X	X	✓
Galvanic isolation.	X	✓	✓	✓
Complete possible battery range (200-1000V)	X	X	✓	✓
Modulability	✓	X	✓	✓

Table 12: Competition matrix for IP2.4.

5.2.5 IP2.5. Algorithms for optimal management of the grid

The “Optimal microgrid management and EV charging” tool consists of two submodules, namely the “optimal microgrid management tool” and the “EV charging algorithms”.

The optimal microgrid management tool employs a set of algorithms that aim to optimally operate the available resources within the REEFLEX project (e.g., residential, commercial and industrial consumers) based on the market conditions and needs to ensure grid stability and maximize profitability in the flexibility markets. This is feasible by exploiting the available flexibility on prosumer-level, which is reported by an independent “Flexibility calculation” tool and leverage it for various flexibility market-related services. This functionality is supported by formulating a separate optimization problem for each market service according to its specific needs, e.g., considering peak shaving service or real-time prices for flexibility provision.

On the other hand, the optimal EV charging tool aims to exploit the rapidly increasing potential of EV charging stations to provide stability services to the grid. For this, a specific suite of algorithms dedicated to optimally manage the related available resources is developed. This submodule facilitates the provision of services, such as peak shaving and load smoothing via real-time energy markets.

BSoA: Although there are multiple tools providing similar services related to microgrid management, the proposed module offers some significant advantages. Specifically, it is designed to operate in different deployment conditions, that is on a cloud service (REEFLEX platform or other proprietary cloud) and on prosumer level e.g., on a gateway device. This interoperability facilitates adaptation of the proposed solution across deployment scenarios and different architectures. Moreover, the tools developed in the context of REEFLEX offer enhanced scalability and can efficiently manage residential, commercial or industrial buildings

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and EV charging stations within a small community as well as in a large industrial complex. This adaptability ensures that the tools can meet the evolving needs of various projects, whether they are expanding or reducing in size. Finally, a significant advantage of the proposed tool is that it ensures real-time optimization within flexibility markets and thus grid stability is robustified against fast or unexpected changes of energy demand or supply. This facilitates rapid decision-making and is crucial for maximizing returns and grid reliability.

Technical Characteristics	Enbala	Grid4C	Smarter Grid Solutions	REEFLEX optimal grid management algorithms
Homogeneous DERs and EVs management	x	✓	X	✓
Customization on different scenarios	✓	X	✓	✓

Table 13: Competition matrix for IP2.5.

5.3 Innovation Pillar 3. Connection and interactions with flexibility markets.

5.3.1 IP3.1. End-users' potential flexibility calculation and aggregation.

Description: The "end-users' potential flexibility calculation and aggregation" set of algorithms try to provide the related tools to provide to the BSP/BRP an easy way of getting on the flexibility market. The most innovative and differentiating aspect of this solution is that it aims to offer the end user the possibility of joining a flexibility aggregator in an easy, fast, and simple way, provided that their installation and devices allow it. To be able to provide flexibility services, it is necessary to address different problems.

On the one hand, it is first necessary to group all available devices and their flexibility capacity, not only by stopping or reducing consumption, but also by offering energy stored in batteries to stop consuming energy from the electrical grid.

Once these capacities have been found, it is necessary, on the one hand, to disaggregate the energy offered by each device in each prosumer to calculate how much energy can be contributed to the system, and to add each of the participants until the necessary amount of energy is reached.

Having already calculated the total energy resulting from all prosumers, it will be necessary to calculate the opportunity cost, to include in the flexibility offer those prosumers who are in an appropriate price range. To do this, it will be necessary to verify that all this will not incur problems in the electrical network that cause deviations and that may cause the opportunity cost to change.

BSoA: REEFLEX's exploration of new aggregation techniques is a crucial step towards the development of flexible energy packages. The fact of trying to achieve aggregation not only through end consumers but also through other BRP/BSP, aims to facilitate reaching the

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minimum energy package necessary for participation in flexibility services, which in Spain is currently 1 MWh. This would allow greater participation in balancing services and therefore a global reduction in energy consumption.

Problems related with the programming unit to participate in flexibility may appear, which in order to tackle, a use of the DSO tool can be made. These tools are also part of the innovative tools expected to be developed within the project.

Competition: Currently, the Spanish legislation mandates that participation in flexibility services is only possible if at least 1MWh is aggregated and all participants must be part of a control centre and the same programming unit. Consequently, the BSP/BRP figure even it is legally possible is hard to reach by aggregation, so there is no competition to analyse at present. While some large consumers participate in flexibility services by reducing consumption, none of them do it right now by aggregation.

5.3.2 IP3.2. Calculation of DSO flexibility needs.

The evolving landscape of the energy sector, characterized by increasing renewable energy integration, distributed generation, the proliferation of electric vehicles and the electrification of other loads, places unprecedented challenges on Distribution System Operators (DSOs). In this context, the development of a tool to calculate DSO flexibility needs, as the one proposed in the REEFLEX project, becomes paramount for DSOs of the future, particularly in managing low voltage grids. The tool's capacity to calculate flexibility needs in both short and long terms addresses the complexities arising from the dynamic nature of energy consumption patterns and the intermittent output of renewable sources. This innovative solution not only enables DSOs to adapt to the changing demands of grid management but also facilitates their active participation in flexibility markets. By offering a standardized approach and integrating historical data, the tool empowers DSOs to analyse, anticipate and respond to grid state across various time horizons. This foresight is crucial for grid resilience, ensuring optimal resource allocation, and facilitating the efficient integration of distributed energy resources.

BSoA: Commercial software is oriented only to asset flexibility optimization and management, such as Schenider's ADMS software, but is not oriented to integration with flexibility markets. Particularly focused on the challenges posed by the integration of renewable energy sources and the dynamic nature of low voltage grids, the REEFLEX project stands out as an innovative initiative. While numerous I+D (Research and Development) projects, such as PARITY and FLEXIGRID within the H2020 framework, are actively contributing to solutions in this domain, the absence of commercial tools indicates a critical gap in the market. The REEFLEX tool, with its emphasis on calculating flexibility needs in both short and long terms for low voltage grids, fills this void by providing DSOs with a tailored and advanced solution to navigate the complexities of the evolving energy landscape.

The competition matrix is as follows:

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Technical Characteristics	ADMS	REEFLEX / Calculation of DSO flexibility needs
Multiple sources of information	✓	✓
Load and demand forecasting	✓	✓
Integration with energy markets tools	X	✓

Table 14: Competition matrix for IP2.5.

5.3.3 IP3.3. Optimal market selection.

Based on the inherent nature of flexibility markets, anticipating the potential features of upcoming energy, reserves, local flexibility and other markets in the next few hours is crucial for optimizing benefits for both generators and consumers. These advantages, beyond purely economic motivations, contribute to the enhanced and prolonged utilization of renewable energy sources (RES) and storage facilities.

The REEFLEX platform will oversee interactions with flexibility markets. It will rely on advanced predictions of the anticipated market behaviour, encompassing both day-ahead and reserve/ancillary services. The resulting tool for selecting the optimal market will equip the platform with a variety of anticipated flexibility market scenarios, organized by probability, and the predicted trends in prices. This allows for the implementation of the most advantageous decisions concerning energy utilization and optimal bidding in the flexibility market

BSoA: In the current market, there are platforms or tools for optimal participation in day-ahead, intraday, or continuous energy markets, which may also include involvement in balancing or frequency markets (in some cases). An example of such tools is the one developed by "enspired" One of the main differences between this tool and the one to be developed within the REEFLEX project is that ours will consider the possibility of interacting in local energy (P2P) and flexibility markets. The competition matrix for the optimal market selection algorithms developed in REEFELX is the following.

Technical Characteristics	ENSPIRED	REEFLEX Optimal market selection
Customization on different scenarios	✓	✓
Intraday and day ahead markets flex markets	✓	✓
Long term flex markets	X	✓
Local P2P	X	✓

Table 15: Competition matrix for IP3.3

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5.3.4 IP3.4. P2P and bilateral energy exchange add-on platform.

Description: The proliferation of DERs has significantly altered the way energy is produced, delivered, and consumed in the energy pipeline, including microgrids. The substantial increase in prosumers should led to a more decentralized and open electrical network.

The problem is that if more prosumers start to be part of flexibility the return on investment of current and future owners of renewable energy systems will likely decrease, which will impact the energy market and cause a ripple effect in other complementary areas throughout society.

In recent years, Peer-to-Peer (P2P) trading has emerged as an alternative for prosumers to actively participate in the energy market. P2P allows prosumers to trade excess energy production with their peers and increase their benefits and consumer benefit. Also, P2P energy trading gives more flexibility to end-users, providing more opportunities to consume clean energy and help transition to a low-carbon energy system.

Additionally, other actors in the electricity market can obtain benefits, such as reducing the peak demand for electricity, reducing maintenance and operation costs, and improving the reliability of the electrical system.

BSoA: The need to connect P2P networks with the rest of the electricity grid so that microgrids and P2P energy exchanges are coordinated with the electricity system operator (TSO) and the energy distributor(s) (DSO) are novel and necessary objectives to be able to implement not only P2P energy exchanges in microgrids, but also so that these microgrids can participate in electricity markets, forming part of the flexibility services they provide.

Microgrids are small-scale power grids that can operate independently or in conjunction with the main power grid. They are capable of generating, storing, and distributing electricity locally, which makes them an ideal solution for remote areas. Peer-to-peer (P2P) energy trading is a next-generation energy management technique that enables prosumers to transact their surplus energy. In a fully decentralised microgrid, prosumers participate in P2P trading, which is a next-generation energy management technique that enables prosumers to transact their surplus energy and reducing the energy needed from the main power grid.

In summary, the integration of P2P energy trading in microgrids is a novel and necessary objective to enable microgrids to participate in electricity markets and form part of the flexibility services they provide.

The most innovative way REEFLEX project adds to P2P energy exchanges is not only the internal grid energy management but also interacting with DSO and TSO to operate in the main power grid to helps to provide flexibility services and avoid power grid congestions.

Competition: Due to the innovative nature of the blockchain usage on microgrids we haven’t be able to find any other competition as a service available right now.

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6 Conclusions

This document corresponds to the deliverable "D2.1 PMV framework and KPIs" which aims to define the foundations for the process of measuring and verification of the services and tools to be developed in the REEFLEX project and deployed in four different demo-sites in four different European countries, Spain, Greece, Switzerland and Bulgaria which are briefly presented to the reader.

To this end a generic M&V process based on the IPMVP has been described. Also, a description and analysis of other protocols has been performed in order to select the more adequate one to the project needs. A brief description of the selected one (in this case the IPMVP) has been also presented.

In addition, several KPIs have been defined not only in line with the nature of the Innovation Pillars that are developed in the project but also in a general way more oriented to evaluate the overall results at demo-site level. Also, contingency KPIs have been defined in case some specific KPI cannot be calculated because lack of data or any other unforeseen reason.

Finally, a brief comparison with similar services in the market (when they are present) is also presented.

As a result, this document provides a general overview of the methodology that will be followed in the demonstration phase of the REEFLEX project which will be conducted in WP6.

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