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Renewable Energy
for Self-Sustainable
Island Communities

WP7 - VALIDATION AND REPLICATION PLAN

D7.1 REACT validation
methodology



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Executive Summary

Task 7.1 aims to define REACT validation methodology to provide an assessment of project results and related use cases from the perspective of energy/cost saving, carbon emission reduction and economic sustainability. The activities of this task are based on the outputs of WP1 (delivering relevant KPIs). Concepts of IPMVP protocol for performance measurement and verification (ISO/DIS 17741), with ongoing EU initiatives such as eeMeasure ICT PSP methodology for energy saving measurement are being considered in this document. Furthermore, this task defines a set of criteria applicable in Task 7.2 to test the whole REACT platform and its components, as well as the control actions upon the underlying energy infrastructure. Task 7.1 defines the data to be collected or measured and design the means how to effectively collect it while respecting the user context and acceptance requirements defined in WP4, considering system performance, functionality, usability, security, and safety. Benchmarking techniques are devised to qualitative evaluate the technical achievement and the satisfaction level. The output of this task is a harmonized validation methodology able to clearly provide an assessment procedure for the application of REACT solution to other geographical islands and respective infrastructures.

Document structure

This document was developed with the help of the partners VEO, FEN, TEK, AIE, R2M, TEES and PUPIN. It is based on the REACT Deliverables 1.1 [1], 1.2 [2], 1.3 [3], 1.4 [4], 3.5 [5], 5.1 [6], 5.2 [2], 6.1 [7], 6.3 [8] and 6.4 [9]. The document structure is:

- **Introduction:** Introduction to the validation methods. Addresses the projects aims and objectives.
- **REACT project expected results:** Describe the objectives of the REACT project in order to guide the reader into a structured process of understanding the validation methodology that will be presented throughout the deliverable.

- **M&V Methodologies - Background:** Provide a general review on what M&V methodologies are, which ones do exist, and on which REACT validation methodology can be based.
- **REACT project validation methodology:** Define REACT validation methodology according to the previous points.
- **Project KPIs:** Based on what was already written in D1.4 [4], that defined relevant Key Performance Indicators able to assess the results of REACT, an updated list of KPIs is described based on the final architecture of the project.
- **Definition of project Use Cases:** Define a set of relevant Demand Response (DR) use cases to help obtain REACT's results, considering the particular conditions of each pilot.
- **Discussion and Conclusions:** Provide a consistent and valuable wrap-up of the deliverable, explain the findings, and summarize the relevant topics.

Key findings and conclusion:

The main objective of this report is to create an M&V process based on the steps designed by the IPMVP protocol, and to aggregate all the necessary information for the validation process from other REACT deliverables in one document to provide a guidance in the calculation of the project results. KPIs and Use cases were described based on the most recent information provided by other deliverables. The output of this task is a validation methodology able to assess the application of the REACT solution from the perspective of energy/cost saving, carbon emission reduction and economic sustainability.

Table of Contents

| | |
|------------------------------------------------------------|----|
| Executive Summary..... | 5 |
| 1. Introduction..... | 14 |
| 2. REACT project expected results | 15 |
| 2.1. REACT Scientific and Technical Objectives (STO) | 16 |
| 3. M&V Methodologies - Background | 19 |
| 3.1. Review of M&V methodologies | 19 |
| 3.1.1. IPMVP..... | 21 |
| 3.1.2. M&V methods used for DR assessment..... | 27 |
| 3.1.3. ICT psp – eeMeasure..... | 28 |
| 3.1.4. Machine learning baseline | 33 |
| 4. REACT project validation methodology..... | 34 |
| 4.1. Quantitative analysis | 35 |
| 4.1.1. Assets installed at the pilots | 35 |
| 4.1.2. Databases description | 36 |
| 4.1.3. M&V plan..... | 39 |
| 4.2. Qualitative analysis..... | 42 |
| 5. Project KPIs | 46 |
| 5.1. Technical | 47 |
| 5.1.1. Systems deployment | 47 |
| 5.1.2. Standardisation and interoperability..... | 47 |
| 5.1.3. Validation of the Integration..... | 48 |
| 5.1.4. Maximisation of intermittent RES utilisation | 49 |

| | | |
|-----------------------------------|--------------------------------------------------------------------------|----|
| 5.1.5. | Ensured grid stability and grid uptime | 50 |
| 5.1.6. | Measurement validation | 51 |
| 5.1.7. | Real-time health monitoring of the grid..... | 52 |
| 5.2. | Environmental | 53 |
| 5.2.1. | Level of energy autonomy | 53 |
| 5.2.2. | Energy cost reduction due to RES and reduction of hydrocarbon fuels | 54 |
| 5.2.3. | RES maximisation to avoid idle capacity | 54 |
| 5.2.4. | RES penetration..... | 55 |
| 5.2.5. | GHG reductions | 56 |
| 5.3. | Economical..... | 56 |
| 5.3.1. | Replication potential | 57 |
| 5.3.2. | Grid OPEX reductions | 57 |
| 5.3.3. | Energy savings | 58 |
| 5.3.4. | Energy costs reductions | 59 |
| 5.3.5. | Business model demonstration | 59 |
| 5.3.6. | Economical savings for end consumers..... | 60 |
| 5.4. | Social | 61 |
| 5.4.1. | Consumer acceptance | 61 |
| 5.4.2. | User engagement and participation in DR programs..... | 62 |
| 5.4.3. | Dissemination activities..... | 63 |
| 6. | Definition of project Use Cases | 64 |
| 6.1. | DR Action 1 - Storage management | 65 |
| 6.2. | DR Action 2 – Maximising self-consumption | 67 |
| 6.3. | DR Action 3 - Using locally produced energy for feed-in | 69 |
| 6.4. | DR Action 4 - End-user appliance control | 71 |
| D7.1 REACT validation methodology | | 8 |

| | | |
|------|------------------------------------------------------------------------|----|
| 6.5. | DR Action 5 - Optimising HP operation | 73 |
| 6.6. | DR Action 6 - Battery reactive power control | 75 |
| 6.7. | DR Action 7 - Frequency and voltage-based battery power controls | 77 |
| 7. | Discussion and Conclusions | 79 |
| | References..... | 81 |

List of Figures

| | |
|-------------------------------------------------------------------------------------------|----|
| Figure 1 - Historical evolution of M&V protocols [15] | 19 |
| Figure 2 - Overview of M&V Design and Reporting Process [12] | 23 |
| Figure 3 - IPMVP framework [12] | 24 |
| Figure 4 - Overview of IPMVP Options [12] | 25 |
| Figure 5 - Typical Project Characteristics and Commonly Favoured IPMVP Options [12] | 26 |
| Figure 6 - M&V Quantifies Load Reduction Value [18] | 27 |
| Figure 7 - Demand response baseline methodologies [11] [19] | 29 |
| Figure 8 - REACT system reference architecture [7] | 34 |
| Figure 9 - Overview of EMS devices deployed at the demonstrator sites [5] | 35 |
| Figure 10 - Grafana visualization of the Aran Islands participant AI11 | 36 |
| Figure 11 - phpMyAdmin web interface | 37 |
| Figure 12 - Data Point List - Example La Graciosa pilot [8] | 38 |
| Figure 13 - REACT Influx data count dashboard - La Graciosa example | 39 |
| Figure 14 - REACT project KPIs per category | 40 |
| Figure 15 - Technology readiness level (TRL) [60] | 49 |
| Figure 16 - Different types of control foreseen with REACT [2] | 64 |

List of Tables

| | |
|-----------------------------------------------------------------------|----|
| Table 1 - Example of a 10 days average baseline [11]..... | 31 |
| Table 2 - Example of TOP average 3 of 10 days baseline [3]..... | 32 |
| Table 3 - Example of Morning adjustment factor calculation [3]..... | 33 |
| Table 4 - Mapping between STO, High Level KPI and KPI Domain [4]..... | 46 |

List of Equations

| | |
|---------------------------------------------------------------------------------|----|
| Equation 1 - Load factor [11]..... | 30 |
| Equation 2 - Average 10 days baseline [11]..... | 30 |
| Equation 3 - DR event consumption for 10 days average [11]..... | 31 |
| Equation 4 - TOP average 3 of 10 days baseline [11] | 31 |
| Equation 5 - DR Consumption TOP average 3 of 10 [11] | 32 |
| Equation 6 - Morning adjustment factor [3] | 32 |
| Equation 7 - DR Consumption TOP average 3 of 10 with Adjustment Factor [3]..... | 33 |
| Equation 8 - KPI - Standardisation and Interoperability [4]..... | 48 |
| Equation 9 - KPI - Validation of integration [4] | 49 |
| Equation 10 - KPI - Supply load factor [4] | 50 |
| Equation 11 – Energy autonomy [4] | 51 |
| Equation 12 - KPI - Measurement Validation..... | 52 |
| Equation 13 - Energy consumption by the grid..... | 52 |
| Equation 14 - KPI – Percentage of renewable energy consumption [4]..... | 53 |
| Equation 15 - KPI - Percentage of energy cost reduction | 54 |
| Equation 16 – KPI – RES maximization [4]..... | 55 |
| Equation 17 - KPI - RES penetration [4] | 55 |
| Equation 18 - KPI GHG reductions | 56 |
| Equation 19 - Percentage of OPEX reduction | 57 |
| Equation 20 - KPI - Energy savings [12] | 58 |
| Equation 21 - KPI - Energy savings [%] | 58 |
| Equation 22 - KPI - Energy cost reduction..... | 59 |
| Equation 23 - KPI - Business model demonstration [4] | 60 |
| Equation 24 - KPI - energy savings for the end consumers [4] | 61 |
| Equation 25 - KPI - Acceptance rate..... | 62 |
| Equation 26 - KPI - User engagement | 62 |
| Equation 27 - KPI - Dissemination activities | 63 |

List of Abbreviations

| | |
|----------------|-----------------------------------------------------|
| ASAP | As Soon As Possible |
| BPM | Baseline profile models |
| DR | Demand Response |
| EEM | Energy Efficiency Measure |
| GUI | Graphical User Interface |
| ICT | Information and Communications Technology |
| IPMVP | International Measurement and Verification protocol |
| KPI | Key Performance Indicator |
| M&V | Measure and Verification |
| RES | Renewable Energy Sources |
| STO | Scientific and technical objectives |
| TRL | Technology Readiness Level |
| UCD | User Centred Design |
| WP | Work Package |

1. Introduction

Measurement and verification (M&V) is the process of planning, measuring, collecting data, analysing, verifying, and reporting energy performance or energy performance improvements for defined M&V boundaries [10]. The M&V methodology definition can affect the project evaluation and a simple and accurate methodology should be provided for a reliable assessment of the project results.

This report will describe the M&V methodology to be used in REACT project, applying techniques already validated by the European Union, such as the ICT PSP [11] considering updates provided by international standards and protocols such as IPMVP [12], ISO 50015:2014 [10], ISO 17741:2016 [13], and ISO 50001:2018 [14]. The objective is to define a validation methodology to provide an accurate assessment to the project's objectives, including KPIs related to the DR use cases for each of the pilot sites from the perspective of energy and cost savings, carbon emission reduction and economic sustainability.

The activities of this task are based on the outputs of WP1 and WP4 of this project and defines the data to be collected or measured, designing the means of how to collect it while respecting the user context and acceptance requirements defined in WP4, considering system performance, functionality, usability, security, and safety.

Finally, this task defines relevant use cases for each pilot site. The output of this task is a validation methodology able to provide an assessment procedure for the application of the REACT solution to other geographical islands, and the outputs of this task will serve as an input for REACT deliverable 7.2 and 7.3, mainly.

2. REACT project expected results

The main objective of REACT project is to support islands to achieve energy independency through maximal exploitation of Renewable Energy Systems (RES) potential and its optimal utilisation by the energy consumption and storage assets. REACT is delivering a scalable and adaptable cloud-based Information and Communications Technology (ICT) platform for planning and management of RES and storage enabled infrastructures to support the energy management strategy at the community levels in geographical islands.

By being cloud-based, REACT enables the grid operators to deploy the REACT solution almost anywhere, reducing the cost to its scalability. Focusing on the community level, the project delivers meaningful impact with synergies between networks and integration with local micro-grids into the energy system of the islands by:

- **Optimisation of multi-carrier energy dispatching** from community owned assets to the end use via synergy of supply and demand optimisation to maximise RES exploitation.
- **Holistic cooperative DR strategy (automated and manual)** to exploit the full flexibility potential of optimal control at the community level.
- **Integration and testing with innovative energy storage technologies** such as environmentally friendly batteries and conventional technologies. Promising technologies, such as hydro storages, are also being considered.
- **Synergy of different energy grids in islands** to integrate based on the availability in the pilots.
- **Deployment of advanced decision support tools** such as energy system operational modelling, short- and long-term forecasting of energy production and consumption, integrated optimisation of energy supply and demand, to significantly reduce the use of hydrocarbon-based energy.

2.1. REACT Scientific and Technical Objectives (STO)

To accomplish and track the progress towards the objectives presented before, Scientific and Technical Objectives (STOs) were described with corresponding targeted metrics identified.

STO1

Increased RES hosting capacity coupled to large-scale energy storage deployment. REACT will increase the penetration of RES generation (regardless of technology) into the existing energy infrastructure, supported by energy storage solutions of adequately scaled capacity and smart-grid compatibility.

Targeted Metrics:

- Reach TRL 7-8 in 3 pilots
- Compliant with interoperability standards (SG-CG, IEC 61970 (CIM), IEC 61850, Open ADR).
- Replication plans & business models for “follower” islands

STO2

Unlock DR potential and optimize distribution grid flexibility. REACT will maximise the use of intermittent RES unlocking the low/medium voltage flexibility through a holistic DR strategy, considering energy demand of island residents in an aggregated way (community level) to enhance the grid security and reliability.

Targeted Metrics:

- Up to 100% utilisation of RES
- 5% grid uptime improvements
- 10% forecast offset corresponding to actual generation/demand profile
- 20% OPEX reductions
- 10% energy savings
- Validations as per IPMVP and eeMeasure

ST03

Lifecycle assessment and long-term plan of RES and storage enabled infrastructure. To support the vision of 100% energy autonomy of islands, REACT will deliver a comprehensive deployment planning of suitable RES generation assets, energy storage solutions, accompanying technologies and (smart) power grid integration.

Targeted Metrics:

- 100% energy autonomy
- 60% energy cost reduction
- >100% RES utilisation

ST04

Engagement of end consumers to cooperatively take an active part in the control loop. REACT will aim to motivate and engage the island residents and building occupants to manually influence the energy demand curve to become an active part of the DR program.

Targeted Metrics:

- 90% acceptance rate
- 80% actively involved in DR activities

ST05

Demonstrators as case studies and early adopters. REACT will be demonstrated in 3 geographical islands, in 3 different countries, in 3 different climate conditions with different RES penetrations. Business ecosystems, business plans and policy and contractual frameworks for wide-scale adoption will be identified and set in motion.

Targeted Metrics:

- 50% increase RES penetration
- 60% GHG reductions
- 60% energy cost reduction
- 10% increased efficiency

ST06

Development of effective business models ready for large-scale replication. REACT will through dedicated project activities prepare the ground and raise awareness for business opportunities and large-scale replication, involving relevant stakeholders such as island communities, technology providers, DSOs, ESCOs, etc.

Targeted Metrics:

- Validation at 3 demo and plans for 5 “follower” islands
- 60% energy cost savings
- 6 workshops organized, 6 journal publications, etc.

3. M&V Methodologies - Background

Simple and accurate Measurement and verification (M&V) methodologies should be provided for a reliable assessment of a project outcome after an Energy Efficiency Measure (EEM). M&V methods can reduce risks for investors in energy performance by providing agreed methods for estimating savings. Nowadays, there are many different methodologies for measurement and verification on the market, each one with specific approaches according to its application. In this chapter, there will be a brief review of some M&V methods, and a description about the validation process to be used in the REACT project.

3.1. Review of M&V methodologies

Measurement and verification (M&V) methods are used to measure and verify, in a defined, disciplined, rigorous and transparent way, the energy savings resulting from implementation of EEMs, which have been planned and designed to improve the energy performance of a specific facility or group of specific facilities [15]. Figure 1 presents the evolution of M&V methods between 1980 and 2010 in a study made by Australasian Energy Performance Contracting Association [15].

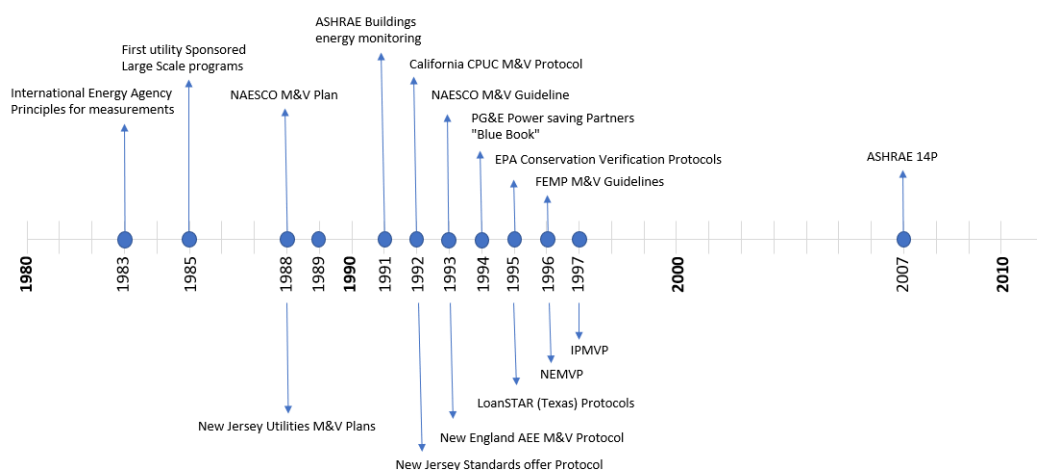


Figure 1 - Historical evolution of M&V protocols [15]

According to the Australasian Energy Performance Contracting Association [15], the development of formal M&V protocols and guidelines started by the increasing use of energy performance contracting in the USA between 1980 and 1990. In the 1990s, investments in energy efficiency started to decrease due to uncertainty regarding the energy savings. In 1994, the US Department of Energy initiated an effort to establish international consensus on methods to determine energy/water efficiency savings and thus promote third-party investment in energy efficiency projects. One of the larger goals of this initiative was to help create a secondary market for energy efficiency investments by developing a consistent set of M&V options applying to a range of energy efficiency measures in a uniform manner resulting in reliable savings over the term of the project.

The voluntary efforts of international experts resulted in the publication of the North American Energy Measurement and Verification Protocol – the NEMVP in 1996. The NEMVP, for the first time, came up with a consistent definition of Options A, B, and C (described in item 3.1.1). In 1997, an updated version of the protocol was published and was renamed the International Performance Measurement and Verification Protocol (IPMVP). While the first version had three M&V Options, a new M&V Option D was included in a second version to recognize the industry practice of using energy simulation tools to determine energy savings by measuring energy use and calibrating the simulation model. The four M&V Options A through D have since become industry standard and are widely used both in the US and abroad.

IPMVP is possibly the most used method of M&V. Although, there are other protocols that share part of the methodology. IPMVP is complemented by the work of ASHRAE who produced Guideline 14P – Measurement of Energy and Demand Savings. ASHRAE Guideline 14 - 2002 focuses on the measurement of energy and demand savings at a very technical level. In contrast, the IPMVP establishes a general framework and terminology for planning and implementing M&V activities. ASHRAE Guideline 14-2002 does not have the equivalent of IPMVP Option A and insist on full measurement. Despite this difference and some differences in terms, ASHRAE Guideline 14 - 2002 is compatible with Volume 1 of IPMVP 2001 (March 2002).

Also, the International Organization for Standardization (ISO) published three standards related to M&V guidance for EMS:

- ISO 50001:2011 – Energy Management System [14]
- ISO 50015:2014 – Energy management Systems – Measurement and verification of energy performance of organizations – General principals and guidance [16]
- ISO 17741:2016 – General technical rules for measurement, calculation and verification of energy savings of projects [13]

In the ISO standards, energy savings are determined by comparing measured and calculated or simulated consumptions before and after the implementation of the EEM with adjustments in relevant variables. It is possible to see the influence of IPMVP in this international regulation. For the REACT project validation methodology definition, all the last versions of these documents are being considered. However, the focus will be on the application of the IPMVP methodology.

3.1.1. IPMVP

IPMVP was originally developed by the US department of Energy with the objective to help increasing investments in energy and water efficiency, demand management and renewable energy project around the world [17].

Due to the benefits of international credibility for energy savings reports, IPMVP is a valid option during the methodology choice. The protocol presents common principles and terms that are widely accepted as basis to M&V process. Though the application of IPMVP may be different to each project, the basis in the M&V plans and implementation is similar.

The IPMVP Core Concepts first version was published in 2014. This document defines the commonly used terminology and guiding principles for applying M&V. It describes the project framework in which M&V activities take place, the contents and requirements of adherent M&V Plans and the attributes of fully adherent IPMVP projects. The last update of this document was in 2022 [4], and due to its direct application in the REACT validation methodology, some concepts are going to be described in this report.

PRINCIPLES OF M&V

The fundamental principles M&V practice described below provide the basis for adherence to IPMVP. These principles should be considered throughout the M&V process.

ACCURATE

M&V Reports should be as accurate as can be justified based on the project value and goals. M&V costs should be small comparing to the monetary value of the savings being evaluated and the accuracy and cost should be evaluated as part of the project development. Accuracy trade-offs should be accompanied by increased conservativeness with increased use of estimated values and assumptions based on engineering judgment.

COMPLETE

The reporting of energy savings should consider all effects of a project. M&V activities should use measurements to quantify energy use within the measurement boundary, document energy influencing factors, and detail any estimated values.

CONSERVATIVE

Where judgments are made about uncertain quantities, M&V procedures should be designed to reasonably estimate savings such that they are not over - or under-stated. An assessment of a project's impact should be made to assure its energy-saving benefits are reasonable with due consideration to the level of statistical confidence in the estimation.

CONSISTENT

The reporting of a project's energy performance should be consistent and comparable across different types of energy efficiency projects, different energy management professionals, different periods for the same project, and new energy supply projects. Consistent does not mean identical since any empirically report involves assumptions based on engineering judgment, which may not be made identically by all reporters.

RELEVANT

The determination of savings should be based on current measurements and information pertaining to the facility where the project occurs. This determination of the savings effort must measure the energy influencing factors and verify performance indicators that are of concern related to the EEM.

TRANSPARENT

All M&V activities should be clearly documented and fully disclosed. Full disclosure should include presentation of all of the elements of an M&V Plan and savings reports. Data and information collected, data preparation techniques, algorithms, spreadsheets, software, assumptions, and analysis should follow best practices, be well documented.

M&V PROCESS

The M&V process based on the IPMVP involves 11 steps. Although, according to the protocol, they do not need to be followed step-by-step and in a timeline. In Figure 2 there is brief description of each step, and the period that usually each step should be performed.

| | |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------|
| Step 1: Determine Goals for M&V Efforts Step 2: Select IPMVP Option(s) and Approaches Step 3: Document Baseline Data Step 4: Develop M&V Plan Step 5: Set-up Metering and Ongoing Data Collection Processes | Baseline Period |
| Step 6: Monitor for Changes in Site Conditions Step 7: Confirm Operational Verification | Installation Period |
| Step 8: Ongoing Data Collection Step 9: Determine Savings for Period Step 10: M&V Report for Period Step 11: Track Energy Performance and Savings | Reporting Period |

Figure 2 - Overview of M&V Design and Reporting Process [12]

This report will focus on the description of the already realized steps in the REACT project, on the baseline and installation periods, and on planning the means of how to perform the steps 8 to 11 in the tasks 7.2 and 7.3 in the reporting period.

IPMVP FRAMEWORK

Energy savings in an installation cannot be directly measured since savings represent the absence of energy consumption or demand. Instead, savings are determined by comparing measured energy before and after implementation of an EEM, making suitable adjustments for changes in conditions. In Figure 3 there is the general savings equation proposed by the IPMVP, and the framework of how to calculate the savings or avoided energy consumption or demand.

$$\text{Savings} = (\text{Baseline Period Energy} - \text{Reporting Period Energy}) \pm \text{Adjustments}$$

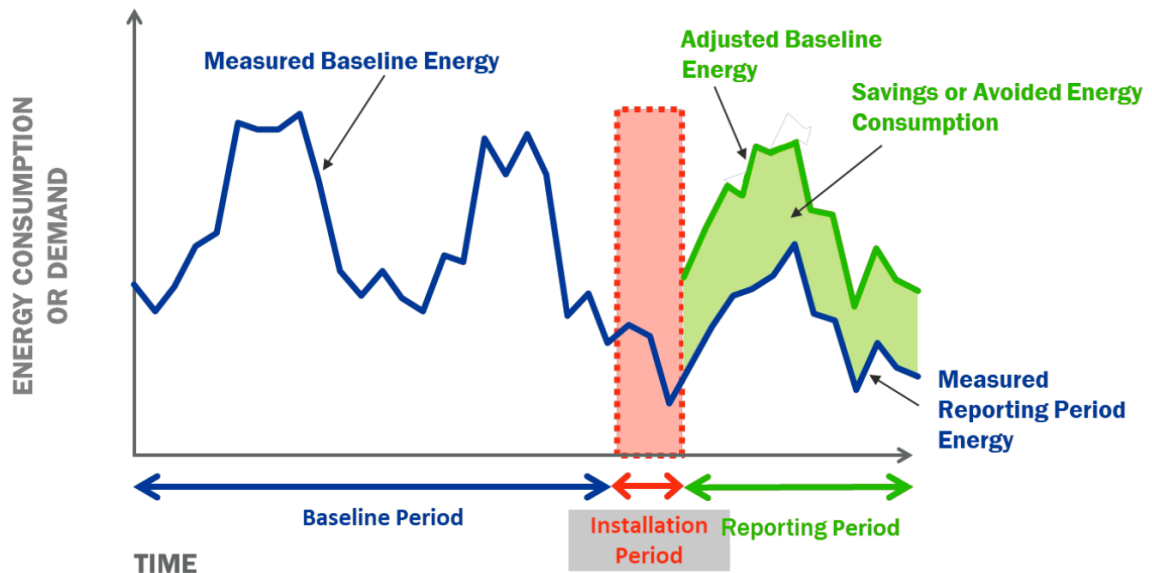


Figure 3 - IPMVP framework [12]

The Adjustments term in this general equation is used to restate the energy use or demand of the baseline and reporting periods under a common set of conditions. Adjustments are made using either mathematical models or physics-based models of energy consumption and/or demand. The Adjustments term distinguishes proper savings reports from a comparison of cost or consumption before and after implementation of an EEM. According to the protocol, simple comparisons without such adjustments report only changes and fail to report the true performance of a project.

IPMVP OPTION SELECTION

The last version of IPMVP contains four options to be used based on the data availability and the characteristics of the energy conservation measure applied. In Figure 4, it is possible to see the four options description, and how they are categorized.

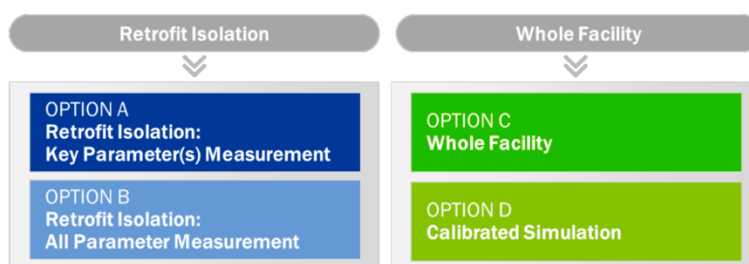


Figure 4 - Overview of IPMVP Options [12]

Option A: Retrofit Isolation, Key Parameter(s) Measurement

Key Parameter(s) Measurement, energy quantities can be derived from a computation using a combination of measurements of some parameters and estimates of the others.

Option B: Retrofit Isolation, All Parameter Measurement

Requires measurement of energy and/or demand, or the key parameters needed to compute energy and/or demand. The savings created by most types of EEMs can be determined with Option B. The degree of difficulty and costs associated with this option increase as metering complexity and comprehensiveness increase. However, Option B will produce accurate savings determination where load or savings patterns are variable.

Option C: Whole Facility

Option C involves the use of energy data from utility meters, whole facility meters, or sub-meters, and independent variables to assess the energy performance of a total facility. This option determines the collective savings of all EEMs applied within the measurement boundary. As such, savings reported under Option C include the positive or negative effects of any non-EEM changes made in the facility.

Option D: Calibrated Simulation

Calibrated Simulation uses facility energy simulation software to predict facility energy use, typically when baseline energy data does not exist. Savings determined with Option D are based on computer simulation models of physical systems which are used to predict facility or process energy consumption and demand. These types of models are based on engineering equations that capture the physics and details of the systems. The accuracy of the savings depends on user proficiency, model robustness, and level of calibration.

According to the protocol, the option should be chosen based on the characteristics of the EEM being applied, and the project available information. In Figure 5 there are some project characteristics descriptions and the most suitable options to be used.

| EEM PROJECT CHARACTERISTIC | Favored Options | | | |
|----------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|---|---|---|
| | A | B | C | D |
| NEED TO ASSESS EEMs INDIVIDUALLY | x | x | | x |
| NEED TO ASSESS ONLY TOTAL FACILITY PERFORMANCE | | | x | x |
| EXPECTED SAVINGS ARE LESS THAN 10% (MONTHLY ENERGY USE DATA) OR 5% (DAILY OR HOURLY ENERGY USE DATA) OF WHOLE FACILITY BASELINE ENERGY CONSUMPTION | x | x | | x |
| THE ENERGY INFLUENCING FACTORS FOR THE EEMs ARE NOT WELL KNOWN | | x | x | x |
| LONG TERM PERFORMANCE ASSESSMENT NEEDED | x | x | x | |
| INTERACTIVE EFFECTS OF EEM ARE SIGNIFICANT OR UNMEASURABLE | | | x | x |
| RECENT OR FUTURE CHANGES ARE EXPECTED TO IMPACT ENERGY USE WITHIN THE MEASUREMENT BOUNDARY | x | | | x |
| BASELINE PERIOD ENERGY DATA ARE NOT AVAILABLE | | | | x |

Figure 5 - Typical Project Characteristics and Commonly Favoured IPMVP Options [12]

3.1.2. M&V methods used for DR assessment

According to the AEIC [18], in DR programs, M&V refers to the application of appropriate techniques to measure and verify the load impact resulting from the utilisation of the Demand Response program. To determine the correct amount of savings during the DR event, it is necessary a good prediction of the demand. Figure 6 shows a one-hour DR event load reduction quantification example, where there is the comparison of the actual load and the expected one.

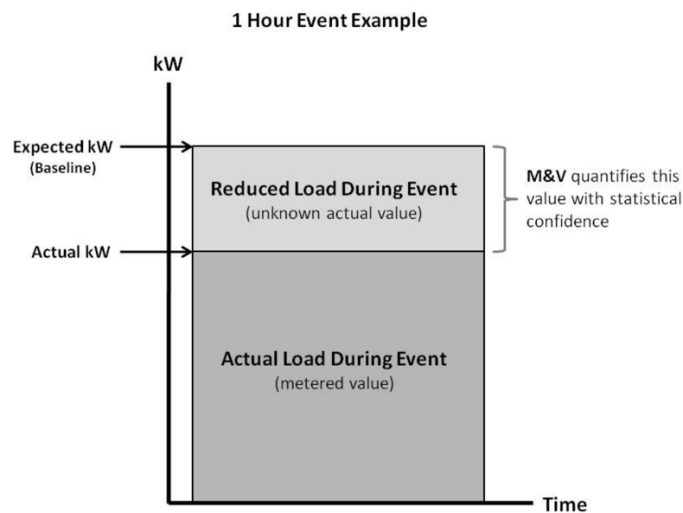


Figure 6 - M&V Quantifies Load Reduction Value [18]

The baseline period is the specified period of time used as reference for comparing with the reporting period [16]. The baseline calculation is a critical piece of DR programs. Depending on the type of demand response, if the baseline for a customer is calculated too high or too low, the electric utility may have to pay incentives in excess or no-load reduction will be recorded, which can lead to customer non-participation in future events. It may also eliminate incentives to participate, resulting in a customer requesting to be removed from the DR program. Therefore, it is in the best interest of all the stakeholders to have as accurate as possible a baseline estimation. [18]

3.1.3. ICT psp – eeMeasure

The original basis for savings calculations within the ICT-PSP projects was a modified version of the EVO International Performance Measurement & Verification Protocol (IPMVP) [11]. The current methodological proposal for ICT PSP projects in the residential sector sets out from the IPMVP and adapts its provisions to the very much smaller scale of energy consumption in the residential sector.

One of the objectives of this method is the attempt to reduce costs of measurement in line with the lower scale of energy consumption by suggesting the use of larger time intervals for measurement and the use of less sub-metering. It was found that the IPMVP approach is in parts applicable to the residential sector specially notions of baseline and methods of calculating savings.

According to this method, when creating the M&V plan, some general topics should be considered along the targets as well as specific conditions at the pilot sites.

- Which is the intervention / are the interventions that shall be evaluated?
- Which is the dependent variable / are the dependent variables that shall be affected by the intervention?
- Which are independent variables that can also have an (unwanted) impact on the dependent variable(s)?

Energy saving approach

According to the ICT PSP approach, measuring energy savings requires estimation of consumption. The result of an energy saving intervention is estimated through comparison of measured energy consumption data before (baseline period) and after the intervention starts (reporting period), similarly to the IPMVP approach.

Summary of steps for estimation from baseline for the energy savings approach:

1. Nominate a period for the baseline which captures all variation of immeasurable independent variables and can yield an average which can reasonably be expected to be repeated in the future

2. Gather data for the energy consumption (dependent variable) and for all accessible independent variables (baseline period)
3. Perform a regression analysis to establish the coefficients for each independent variable
4. Nominate the reporting period which is long enough to capture all variation of immeasurable independent variables
5. Gather data for the energy consumption (dependent variable) and for all accessible independent variables (reporting period)
6. Apply the coefficients estimated in the baseline to the reporting period, yielding the result: energy saving as the difference between estimated and measured consumption.

Peak demand reduction approach

Whereas interventions aimed at energy savings target overall energy use, e.g., over a specified period like a month or a year, the intervention in the peak demand reduction involves a decrease in the load in a certain period, when demand from all customers peaks.

Demand response baseline methodologies for the peak load reduction approach according to the methodology are described in Figure 7:

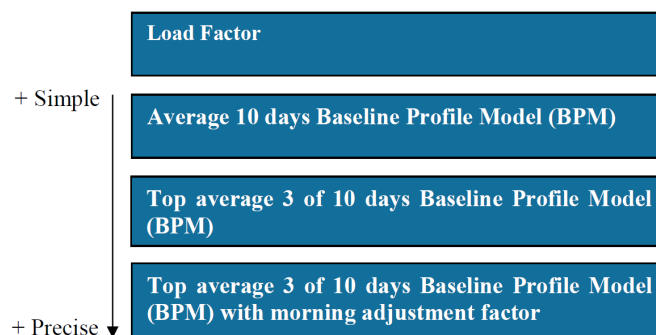


Figure 7 - Demand response baseline methodologies [11] [19]

- Load factor

The load factor (LF) is defined as the value obtained by dividing the minimum power demand by the maximum power demand of a building.

$$LF = \frac{(\text{min power demand})}{(\text{max power demand})}$$

Equation 1 - Load factor [11]

The closer the load factor is to the value 1, the less the energy curve peaks. If the building load curve peaks correspond to the electricity network peaks, movement towards 1 can represent useful peak shaving for the utility. Also, the literature shows that the load factor can be calculated using the average power demand instead of minimum power demand.

- Average 10 days baseline profile model

Baseline profile models (BPL) are used to estimate the peaks which occur on particular days. To estimate consumption at the peak event, it is generally accepted a baseline period of 10 business days directly prior to the event day. The reporting period is typically the 24 hours of the event day. A 10-day baseline time frame is short enough to account for near-term trends and long enough to limit opportunities for manipulation. In this model the average represents the event day baseline estimate. The consumption over the 10 days is averaged as can be seen in Equation 2.

$$b = \frac{d1(t, h) + d2(t, h) + d3(t, h) + d4(t, h) + d5(t, h) + d6(t, h) + d7(t, h) + d8(t, h) + d9(t, h) + d10(t, h)}{10}$$

Equation 2 - Average 10 days baseline [11]

t: day of the event

h: hour of the event

The actual consumption on the event day is compared to this average to quantify the peak shaving as can be seen in Equation 3.

$$DR_{consumption} = Demand_{event\ day} - Baseline_{average}$$

Equation 3 - DR event consumption for 10 days average [11]

In Table 1, there is an example of a baseline creation using this method.

| Power Demand [kWh] | |
|--------------------|-------------|
| Day 1, hour 20:00 | 4,00 |
| Day 2, hour 20:00 | 4,15 |
| Day 3, hour 20:00 | 4,00 |
| Day 4, hour 20:00 | 3,90 |
| Day 5, hour 20:00 | 4,00 |
| Day 6, hour 20:00 | 4,30 |
| Day 7, hour 20:00 | 3,85 |
| Day 8, hour 20:00 | 4,05 |
| Day 9, hour 20:00 | 3,95 |
| Day 10, hour 20:00 | 4,10 |
| Baseline | 4,03 |

Table 1 - Example of a 10 days average baseline [11]

- **Top average 3 of 10 days baseline**

Considering some possible issues with simply averaging 10 previous days as baseline, other methods specify the averaging of the 3 highest consumption periods from the previous 10 days, which must exclude other event days, holidays etc. Equation 4 shows how to calculate the average of this values.

$$b: \max(1,3) \frac{(\sum dn(t, h))}{3}$$

Equation 4 - TOP average 3 of 10 days baseline [11]

t: day of the event

h: hour of the event

The actual consumption on the event day is compared to this average to quantify the peak shaving as can be seen in Equation 5.

$$DR_{consumption} = Demand_{event\ day} - Baseline_{average}$$

Equation 5 - DR Consumption TOP average 3 of 10 [11]

In Table 2, there is an example of a baseline creation using this method.

| Power Demand [kWh] | |
|--------------------|-------------|
| Day 1, hour 20:00 | 4,00 |
| Day 2, hour 20:00 | 4,15 |
| Day 3, hour 20:00 | 4,00 |
| Day 4, hour 20:00 | 3,90 |
| Day 5, hour 20:00 | 4,00 |
| Day 6, hour 20:00 | 4,30 |
| Day 7, hour 20:00 | 3,85 |
| Day 8, hour 20:00 | 4,05 |
| Day 9, hour 20:00 | 3,95 |
| Day 10, hour 20:00 | 4,10 |
| Baseline | 4,18 |

Table 2 - Example of TOP average 3 of 10 days baseline [3]

- **Top average 3 of 10 days baseline with morning adjustment factor**

Considering that customer demand is often heaviest on event days, capturing the differences in a customer load profile is essential to deliver accurate performance calculations. A simple way to address this is through an adjustment based on day-of event conditions. Equation 6 shows a method for adjusting the event day.

$$P: \frac{d(t, h - 1) - b(t, h - 1) + d(t, h - 2) - b(t, h - 2)}{2}$$

Equation 6 - Morning adjustment factor [3]

The actual consumption on the event day can be seen in Equation 7.

$$DR_{consumption} = Demand_{event\ day} - Baseline_{average} + adjustment\ factor$$

Equation 7 - DR Consumption TOP average 3 of 10 with Adjustment Factor [3]

| | Power Demand [kW] | Baseline [kW] | |
|---------------------------|-------------------|---------------|-------------|
| Day 11, hour 18:00 | 4,00 | 3,50 | 0,5 |
| Day 11, hour 19:00 | 4,15 | 3,75 | 0,4 |
| Adjustment factor | | | 0,45 |

Table 3 - Example of Morning adjustment factor calculation [3]

3.1.4. Machine learning baseline

Load forecasting for small scale residential buildings is a more complex process than the conventional forecasting methodologies [20]. This is due to the load time-series for residential buildings with low aggregation be highly non-smooth and exhibit a volatile and chaotic behaviour [21]. The accuracy of the forecasting methodologies is closely related to the size of the network and the level of aggregation [20] [22]. The available literature suggests that conventional statistical methods may not work well when the number of residential buildings are small [22].

In [23], 5 baseline methodologies (Machine Learning, Polynomial extrapolation, Regression, Last 10 days California ISO, High 5 of 10 New York ISO) are compared for 66 DR participating residential customers of Australian energy company. The results showed that machine learning produces the smallest bias among the methods which means it has the least tendency to over or under predict the baseline.

REACT deliverable 5.1 [6], describes the efforts to create the prediction algorithms in the project and the results show an acceptable level of accuracy for the data being used so far. These models still need to be re-trained with the data from the pilots to guarantee that the prediction algorithms can be used for the validation of the project.

4. REACT project validation methodology

The REACT project validation will be based on the methodologies presented in Chapter 3. The definition of the data to be collected or measured and the design of the means on how to do it also will be included in this chapter. Deliverable 6.1 [7] contains information about the REACT reference architecture components as shown in Figure 8.

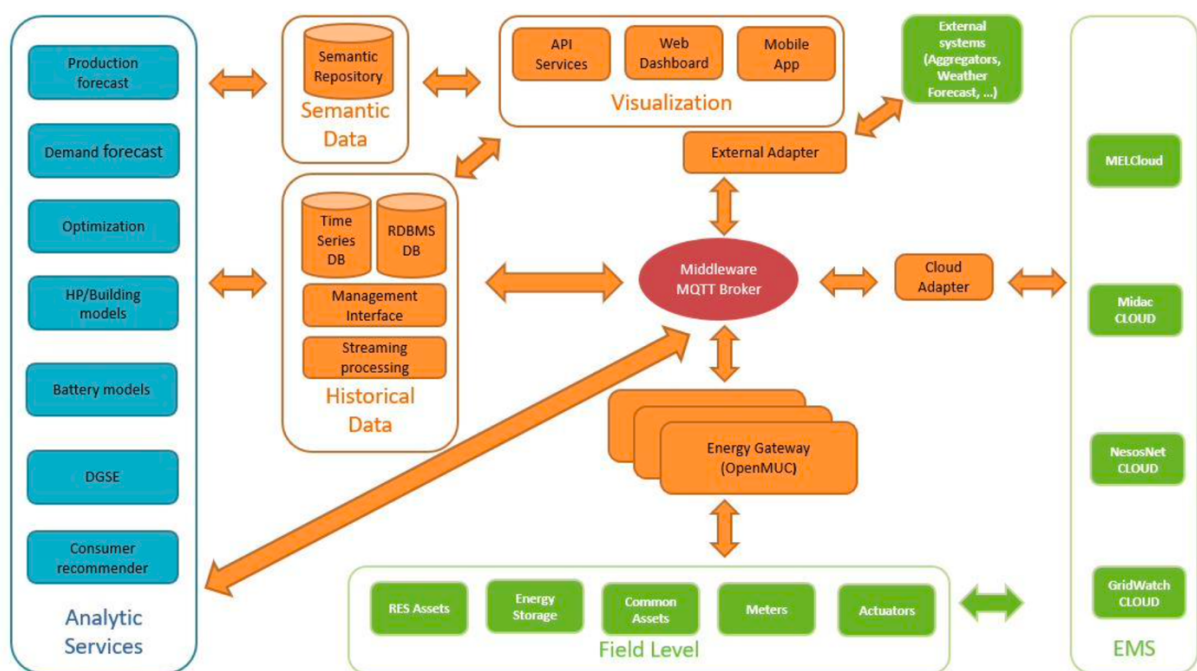


Figure 8 - REACT system reference architecture [7]

The most common issues for Performance Measurement & Verification assessment is the development of the baseline, which in REACT is being addressed with the adoption of the demand forecast, and time series database services. These services aim to provide a most accurate estimation of electrical demand via predictive models. The models provide a continuous calibrated baseline to obtain higher accuracy.

The REACT services involved in the M&V framework will be:

- Analytic services → Weather data, monitoring data, and forecasting data

- Historical Data → Real energy historical information
- Semantic Data → Data point list with pilot information

4.1. Quantitative analysis

The quantitative analysis will be based on the theory presented about the M&V methodologies. In this section, there is a brief description about the assets installed in each pilot, databases description, KPI definition and categories, baseline adjustment information and a brief use case definition description.

4.1.1. Assets installed at the pilots

REACT will couple RES technologies available in the pilots (community assets) and from consortium technology providers, with innovative energy storage technologies, and with a necessary know-how and ICT expertise to ensure most efficient, stable and reliable grid operation. Combining these RES and Storage technologies will allow REACT to provide benefits to both energy grid stakeholders and end consumers.

In Figure 9 it is possible to see a list of devices deployed by the project in each pilot.









| Category | | Heat Pumps | | PV + Inverter | | Battery | EMS / Smart Meter | | Other |
|--------------------|-------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Field Devices | | Residential ATW / ATA (MERCE) | Commercial CityMulti VRF / CAHV (MERCE) | Victron (ORD) | SMA (ORD) | Midac (MID) | Nesos (R2M) | Gridwatch (ESBN) | NASCA Plant / P2H System etc. |
| Image | |  |  |  |  |  |  |  |  |
| Interface | | MELcloud | RMI MCC | OpenMUC G/W | | MIDAC Cloud | Nesos Net | Gridwatch Cloud | Bespoke |
| Access Type | | R/W | R R/W | R/W | R/W | R/W | R | R | R/W |
| Communication Type | | Cloud-based API | Cloud-based API | MQTT | | MQTT | MQTT | MQTT | Modbus |
| Pilot | Aran | • | | • | • | | | • | P2H, V2G |
| | La Graciosa | | | • | | | | | V2G |
| | San Pietro | • | • | • | | • | • | | |

Figure 9 - Overview of EMS devices deployed at the demonstrator sites [5]

4.1.2. Databases description

REACT project architecture is described through the deliverable 6.1 [7]. In this section, there is a brief description of the databases important for the M&V validation plan.

InfluxDB

InfluxDB represents a database designed to handle high write and query loads of time-series data as well as down sampling and expiring old data. Its purpose is to be used as the data storage for large amounts of time stamped data, including IoT sensor data, DevOps monitoring, application metrics, and real-time analytics [7]. To visualize the information stored in the database, the Grafana application is being used. Grafana is a Graphical User Interface (GUI) for querying the influx database and automatic plotting that allows you to query, visualize, and create alerts regarding the data being stored when necessary [24]. In Figure 10 there is an example of visualization from the data stored in the Influx database from the Aran Islands participant A11 in the Grafana application. In REACT, the application of this database is to store all the historical data from the buildings.

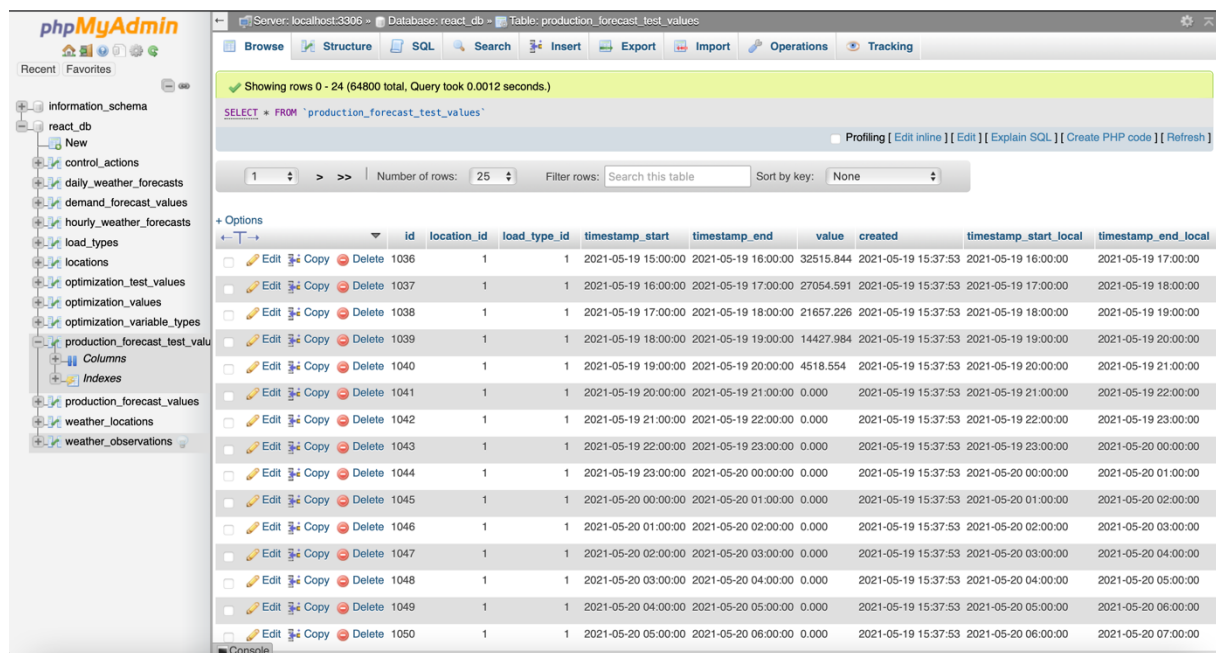


Figure 10 - Grafana visualization of the Aran Islands participant A11

phpMyAdmin

phpMyAdmin is a software tool written in PHP, intended to handle the administration of MySQL over the Web. phpMyAdmin supports a wide range of operations on MySQL and MariaDB. Frequently used operations (managing databases, tables, columns, relations, indexes, users, permissions, etc) can be performed via the user interface, while you still have the ability to directly execute any SQL statement [25].

In REACT, this relational MySQL database is being used to store the intermediary results of the analytic services (e.g., forecasting, optimization, etc.). In Figure 11 there is an image example of one of the tables that stores production forecast test values being accessed by the web interface.



| | id | location_id | load_type_id | timestamp_start | timestamp_end | value | created | timestamp_start_local | timestamp_end_local |
|-------------------------------------------|------|-------------|--------------|---------------------|---------------------|-----------|---------------------|-----------------------|---------------------|
| <input type="checkbox"/> Edit Copy Delete | 1036 | 1 | 1 | 2021-05-19 15:00:00 | 2021-05-19 16:00:00 | 32515.844 | 2021-05-19 15:37:53 | 2021-05-19 16:00:00 | 2021-05-19 17:00:00 |
| <input type="checkbox"/> Edit Copy Delete | 1037 | 1 | 1 | 2021-05-19 16:00:00 | 2021-05-19 17:00:00 | 27054.591 | 2021-05-19 15:37:53 | 2021-05-19 17:00:00 | 2021-05-19 18:00:00 |
| <input type="checkbox"/> Edit Copy Delete | 1038 | 1 | 1 | 2021-05-19 17:00:00 | 2021-05-19 18:00:00 | 21657.226 | 2021-05-19 15:37:53 | 2021-05-19 18:00:00 | 2021-05-19 19:00:00 |
| <input type="checkbox"/> Edit Copy Delete | 1039 | 1 | 1 | 2021-05-19 18:00:00 | 2021-05-19 19:00:00 | 14427.984 | 2021-05-19 15:37:53 | 2021-05-19 19:00:00 | 2021-05-19 20:00:00 |
| <input type="checkbox"/> Edit Copy Delete | 1040 | 1 | 1 | 2021-05-19 19:00:00 | 2021-05-19 20:00:00 | 4518.554 | 2021-05-19 15:37:53 | 2021-05-19 20:00:00 | 2021-05-19 21:00:00 |
| <input type="checkbox"/> Edit Copy Delete | 1041 | 1 | 1 | 2021-05-19 20:00:00 | 2021-05-19 21:00:00 | 0.000 | 2021-05-19 15:37:53 | 2021-05-19 21:00:00 | 2021-05-19 22:00:00 |
| <input type="checkbox"/> Edit Copy Delete | 1042 | 1 | 1 | 2021-05-19 21:00:00 | 2021-05-19 22:00:00 | 0.000 | 2021-05-19 15:37:53 | 2021-05-19 22:00:00 | 2021-05-19 23:00:00 |
| <input type="checkbox"/> Edit Copy Delete | 1043 | 1 | 1 | 2021-05-19 22:00:00 | 2021-05-19 23:00:00 | 0.000 | 2021-05-19 15:37:53 | 2021-05-19 23:00:00 | 2021-05-20 00:00:00 |
| <input type="checkbox"/> Edit Copy Delete | 1044 | 1 | 1 | 2021-05-19 23:00:00 | 2021-05-20 00:00:00 | 0.000 | 2021-05-19 15:37:53 | 2021-05-20 00:00:00 | 2021-05-20 01:00:00 |
| <input type="checkbox"/> Edit Copy Delete | 1045 | 1 | 1 | 2021-05-20 00:00:00 | 2021-05-20 01:00:00 | 0.000 | 2021-05-19 15:37:53 | 2021-05-20 01:00:00 | 2021-05-20 02:00:00 |
| <input type="checkbox"/> Edit Copy Delete | 1046 | 1 | 1 | 2021-05-20 01:00:00 | 2021-05-20 02:00:00 | 0.000 | 2021-05-19 15:37:53 | 2021-05-20 02:00:00 | 2021-05-20 03:00:00 |
| <input type="checkbox"/> Edit Copy Delete | 1047 | 1 | 1 | 2021-05-20 02:00:00 | 2021-05-20 03:00:00 | 0.000 | 2021-05-19 15:37:53 | 2021-05-20 03:00:00 | 2021-05-20 04:00:00 |
| <input type="checkbox"/> Edit Copy Delete | 1048 | 1 | 1 | 2021-05-20 03:00:00 | 2021-05-20 04:00:00 | 0.000 | 2021-05-19 15:37:53 | 2021-05-20 04:00:00 | 2021-05-20 05:00:00 |
| <input type="checkbox"/> Edit Copy Delete | 1049 | 1 | 1 | 2021-05-20 04:00:00 | 2021-05-20 05:00:00 | 0.000 | 2021-05-19 15:37:53 | 2021-05-20 05:00:00 | 2021-05-20 06:00:00 |
| <input type="checkbox"/> Edit Copy Delete | 1050 | 1 | 1 | 2021-05-20 05:00:00 | 2021-05-20 06:00:00 | 0.000 | 2021-05-19 15:37:53 | 2021-05-20 06:00:00 | 2021-05-20 07:00:00 |

Figure 11 - phpMyAdmin web interface

REACT ontology – Data Point List

Ontologies aim to support Semantic Repositories enabling the exploitation of the collected raw data. The aim of the REACT ontology is to adequately represent the information of the different pilot sites regarding the equipment installed, measurement characteristics of the device that is sending to the historical database (e.g., frequency, production power, etc...) as well as the inherent features of the facilities involved in the pilot site. This information is collected by the pilot in the form of Excel files called Data Point Lists. Figure 12 shows an example of the data point list of the La Graciosa pilot.

| Unique identifier of the facility where the equipment is installed | Category of the facility | Date when the facility installation was finished | Energy carriers present in a given facility as local generators | Energy carriers present in a given facility as demand | Topology of the facility |
|--------------------------------------------------------------------|--------------------------|--------------------------------------------------|-----------------------------------------------------------------|-------------------------------------------------------|--------------------------|
| Free input | Select from the list | Free input | Free input | Free input | Select from the list |
| Location_facility_id | Facility_category | Facility_membership_date | Generation_energy_carriers | Demand_energy_carriers | Facility_topology |
| LG4 | residential | 02/12/2020 | electric | electric | DC Coupled |
| LG11 | residential | 02/12/2020 | electric | electric | DC Coupled |
| LG27 | residential | 02/12/2020 | electric | electric | DC Coupled |
| LG18 | residential | 16/06/2021 | electric | electric | DC Coupled |
| LG2.1 | residential | 02/12/2020 | electric | electric | DC Coupled |

Figure 12 - Data Point List - Example La Graciosa pilot [8]

For more information about the structure, how this ontology was developed, and how to use in other applications, please refer to the Deliverable 6.3 [8].

Data quality evaluation tool

REACT Influx data count dashboard displays a heatmap of how many measurements of a particular type have been recorded in the selected pilot site at each day in the selected range. The main objective of this tool is to help in the evaluation of data quality of the historical data stored in the REACT platform. This tool is very important for the evaluation of the data stored in the platform during the validation. If there is not enough quality to create a baseline for a specific building, this one should not be considered during the validation process. Figure 13 shows an example of the data count for the variable max production power in the La Graciosa pilot between February and March of 2022.

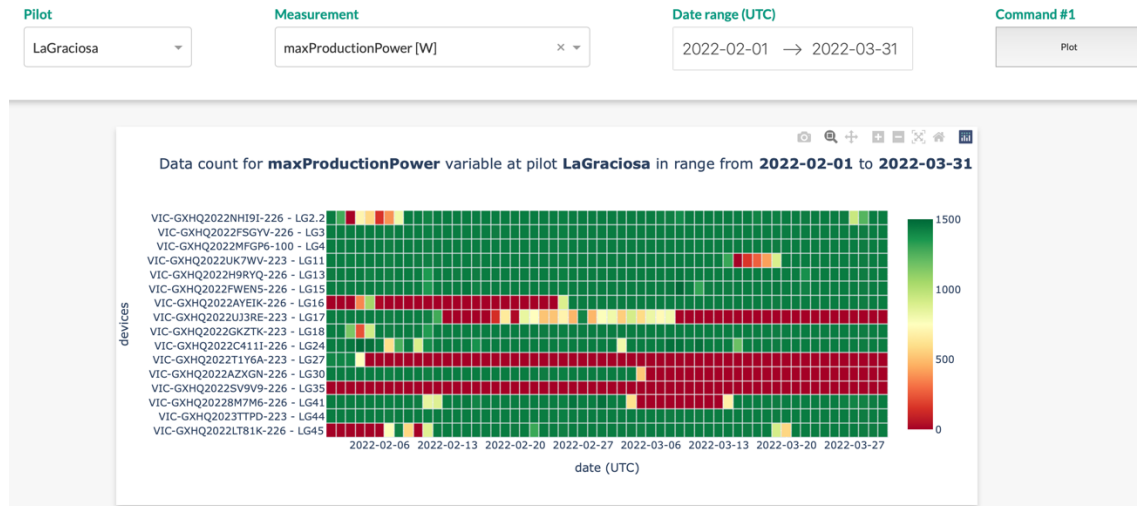


Figure 13 - REACT Influx data count dashboard - La Graciosa example

4.1.3. M&V plan

Focusing on all the aspects presented before in this report, this section will show the relevant steps to validate the project objectives. The focus of this report will be on energy/cost savings, carbon emission reduction and economic sustainability. The KPIs for the targeted metrics not related to these aspects of the STOs are being described in this document but will be evaluated in the applicable work packages.

KPIs

In Section 2.1, the STOs of the REACT project are described along with the targeted metrics for their validation. For each targeted metric, there is a KPI methodology calculation applicable. Deliverable 1.4 [4] includes all the KPIs descriptions and formulas categorized for the validation of the REACT project. In this deliverable, some KPIs will be updated based on the available information being collected in the pilots and recategorized when necessary. Chapter 5 contains all the KPIs descriptions and equations related to the project targeted metrics. Also, information about how to collect data to

calculate the KPIs included in this chapter. Figure 14 shows the KPIs description and its categories.

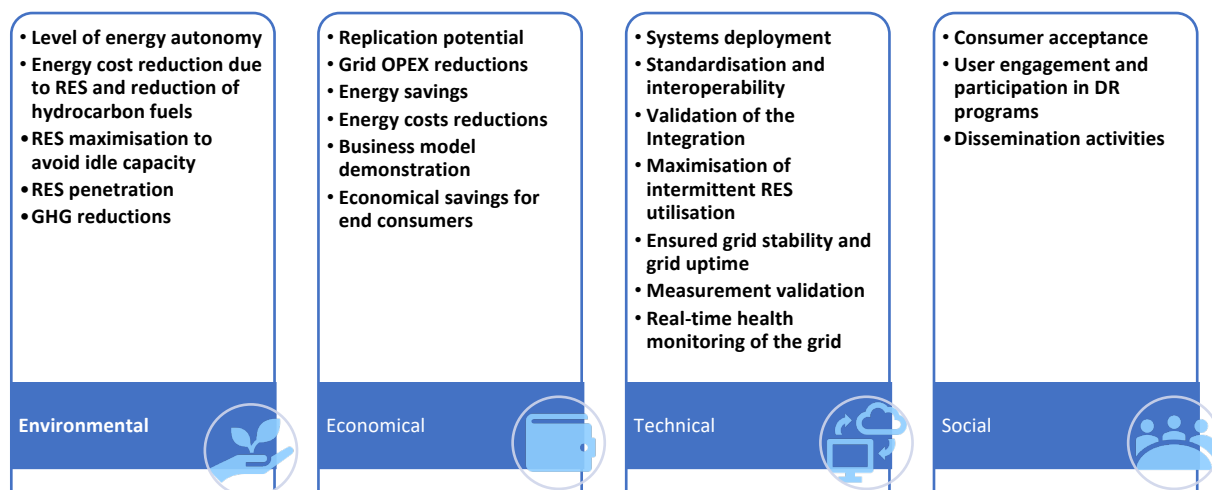


Figure 14 – REACT project KPIs per category

Adjusted baseline calculation

As presented before, one of the most important issues in the validation methodologies is the development of the baseline. In the REACT project, the baseline data source will depend on the quality of the information collected by the pilots' devices. If possible, it is advised to use as baseline the information provided by the forecast services for the DR events. When this information is not available, techniques described in topic 3.1.3 are advised to create the adjusted baseline for calculating the outcomes of the project.

The resolution of the data collection for the baseline period will depend on the approach of the use case. Each use case contains specific characteristics, and it is important to understand in its application what is relevant for the accuracy of the validation (for more information about the principles of a good M&V practice, please refer to the topic 3.1.1- IPMVP – Principles of IPMVP in this report).

When necessary, there is also available information from before the start of the REACT project installations. This data was collected by the pilots in WP01, and in Deliverables 1.1 [1], and 1.3 [3] there are information that can be used in this regard.

Use Cases

The Use Case definition is an important part of the validation process, since this will guarantee that the type of baseline created is adequate considering the objectives of the action performed. Chapter 3 of Deliverable 1.2 [2] described the different types of possible DR actions to be performed, and Deliverable 5.2 [2] describes the possible DR strategy for the REACT project.

REACT project use cases were described considering the following control actions outcome groups [2]:

- Automatized actions (automatically executed by platform, e.g., storage management)
- Hybrid actions (executed repeatedly and automatically by platform after consent is given)
- Prescriptive actions (specific suggestions for users to confirm)
- Descriptive actions (fallback method, general suggestions for users to implement manually)

The DR use cases to be evaluated by this M&V plan are described in chapter 6 of this report, and the information is based on the information obtained on the REACT WP 01 deliverable 1.3 [3].

4.2. Qualitative analysis

Whilst quantitative approaches will be used to measure user acceptance rate and engagement with DR programmes, understanding how people are engaging with the technology and why requires a qualitative approach and analysis. Previous studies have started to investigate the social impact of DR by exploring how the required levels of flexibility intersect with social norms and everyday practices [26, 27]. An overview of the literature of qualitative approaches have shown how the implementation of DR in people's homes affected their family routines [28], and that different appliances could be shifted in varying ways [29] whilst an exploration a heat pump trial in social housing exposed how households' choices and control of heating and cooling in their homes can have detrimental effects on their health and well-being [30]. As such, empirical analysis of the users' interaction with and acceptance of DR is important if we are to thoroughly understand the real world impacts of different design options for DR technologies, interfaces and DR actions.

To understand how the REACT technology and platform is likely to be received in the context of island communities, qualitative analysis of the user experience in the REACT demonstrations at the three pilot islands will be conducted. The three islands offer different social contexts: comprised of social, environmental and economic characteristics. The differences in the design of the REACT pilots at the three islands will also impact on the results in terms of user acceptance and engagement. A relevant concept to measure is what Powell and Fell [31] refer to as 'flexibility capital', which is the ability of individuals, households, communities, families and businesses to be flexible in terms of their use of energy, i.e. having the ability to shift their energy consumption "in time and space, or through changes in intensity or vector" (p. 57), e.g. moving from gas or LPG to electricity.

'Flexibility capital' is determined by several factors including working patterns, dominant social practices, demographic characteristics in the case of households, including the life stage [32], wealth, etc. Technically, the attributes of homes or places of

work (including the availability of energy storage and energy requirements) play an important part, in addition to intangible factors such as culture and religion. All these factors intersect to shape what we refer in the REACT study as the ‘social context’. Crawley et al. [33] in their comparison of different DR demonstrations show how impacts on users differed significantly depending on the social context. Therefore, to capture the effect of the social context, an in-depth exploration of people’s experiences with the technology is imperative. This will require a qualitative approach, which in REACT will include interviews and focus group discussions. This will be crucial in order to understand and bring out the differences between the islands and among the participants in each pilot in relation to (1) perceptions of the technology with respect to the community’s needs, (2) levels of acceptance in relation to the participating households’ priorities and requirements, and the (3) optimal levels of engagement available to different participants given the social norms prevalent in each community – routines, family life, and livelihoods.

Furthermore, the qualitative study will help us explore the differences among energy users in non-residential sites. Public sector and community buildings, as well as private non-residential establishments that are participating in the REACT platform will have different needs and requirements when it comes to electricity consumption. Furthermore, depending on the type of work that is taking place in a specific building, the available flexibility capital will be different [34, 35]. Motivations to modify energy consumption at work vary across the types of work taking place, the building attributes, and the distributed levels of responsibility and interest amongst employees and business owners, if applicable. This necessitates different methods to be employed to capture these elements and nuances.

Therefore, the REACT qualitative analysis will involve:

- In the case of **residential pilot participants**, the research will involve a sample of in-depth interviews and a post-trial survey to measure overall satisfaction with the project as well as validate insights from the Technology Acceptance Model (TAM) questionnaire. The in-depth interviews with residential users will explore:

- Required levels of domestic management (how entrenched is the interaction with REACT with household routines and requirements) [29]
- Existing levels of automation (which appliances, the routines they impact and the total number of appliances controlled) [36, 37]
- Distribution of responsibility (responses to nudges and encouragements compared to direct requests) [38]
- Household motivations and family values [39, 40]
- Building attributes and assets [41]
- Social norms and practices, including leisure and work-related routines and practices. By considering social practices, we take into consideration the material dependencies, meanings and distributed competences that shape these activities and impact the energy consumption associated with them [42]
- Thermal comfort practices, including the use of individual or central heating or cooling systems [43-45]
- Demographic characteristics and life stage of household members (e.g. children's age, associated needs, retirement preferences and plans) and gender preferences [46, 47]
- Knowledge and understanding of DR and smart grid concepts and technologies [30, 48]
- In the case of the qualitative evaluation of user experience in **non-residential buildings**, focus groups will be conducted with building owners/managers and focus groups with workplace employees. The focus groups with non-residential users will explore:
 - Required levels of workplace management (how entrenched is the interaction with REACT with workplace needs) [49]
 - Existing levels of automation compared to required user engagement [50]
 - Distribution of responsibility (responses to nudges and encouragements compared to direct requests) [38, 50, 51]

- Worker motivations and organizational culture [52]
- Building attributes and assets [41]
- Thermal comfort practices, including the use of individual or central heating or cooling systems [53, 54]
- Knowledge and understanding of DR and smart grid concepts and technologies [30, 48]
- Social relations at work (including organizational culture) and group dynamics [51, 55]
- Organizational practices and management decisions (including environmental interventions) [56, 57]
- Existence and role of a facilities manager (especially in large and multi-occupancy office buildings) [58]

Both methods will explore how the different readiness levels impacted on the implementation and satisfaction with the experience of taking part in the REACT project pilots. The approach will build on readiness levels identified in previous research on DR in non-residential buildings [59] and explore the organisational readiness in these buildings. Alongside interviews and focus group discussions, a short survey questionnaire will be conducted with the participants to collect socio-economic information (such as age, income levels, size of home). Information on the buildings collected as part of the demonstrations will also be used to triangulate the qualitative data collected from the interviews and focus groups.

5. Project KPIs

Based on the STOs, the KPIs here described can validate the targeted metrics identified and already presented in section 2.1. Deliverable 1.4 [4] defined all the KPIs of the REACT project, explaining in details their application and calculation methods. Table 4 extracted from this deliverable shows the correlation between the STOs, the KPIs and their domains.

| STO | High Level KPI | Domain |
|------|---------------------------------------------------------------------|---------------|
| STO1 | Systems deployment | Technical |
| STO1 | Standardisation and interoperability | Technical |
| STO1 | Validation of the Integration | Technical |
| STO1 | Replication Potential | All |
| STO2 | Maximisation of intermittent RES utilisation | Technical |
| STO2 | Ensured grid stability and grid uptime | Technical |
| STO2 | Grid OPEX reductions | Economical |
| STO2 | Energy savings | Economical |
| STO2 | Measurement validation | Technical |
| STO2 | Real-time health monitoring of the grid | Technical |
| STO3 | Level of energy autonomy | Environmental |
| STO3 | Energy cost reduction due to RES and reduction of hydrocarbon fuels | Environmental |
| STO3 | RES maximisation to avoid idle capacity | Environmental |
| STO4 | Consumer acceptance | Social |
| STO4 | User engagement and participation in DR programs | Social |
| STO5 | RES penetration | Environmental |
| STO5 | GHG reductions | Environmental |
| STO5 | Energy costs reductions | Economical |
| STO5 | Energy savings | Economical |
| STO6 | Business model demonstration | Economical |
| STO6 | Economical savings for end consumers | Economical |
| STO6 | Dissemination activities | Social |

Table 4 - Mapping between STO, High Level KPI and KPI Domain [4]

In the next sections, a brief description of each KPI with an enhanced calculation methodology and the targeted metric correlation will be provided based on the information from Deliverable 1.4 [4].

5.1. Technical

The technical KPIs evaluate the REACT platform using indicators to measure the systems performance, the level of standardisation of the platform, the integration between installed assets and the platform, grid health monitoring and stability, and optimal control. The targeted metrics to be validated using the technical KPIs are:

- Comply with interoperability standards (SG-CG, IEC 61970 (CIM), IEC 61850, Open ADR).
- Reach TRL 7-8 in 3 pilots
- Up to 100% utilisation of RES
- 5% grid uptime improvements
- Validations as per IPMVP and eeMeasure2
- 10% forecast offset corresponding to actual generation/demand profile

These metrics are related to STO1 and STO2.

5.1.1. Systems deployment

The KPIs related to systems deployment aim to measure the performance of systems installed by the project, focusing specially on the heat pumps, PV systems, and battery performance measurements. The information about the outcomes of these KPIs calculations can be found in WP 03 deliverables. Systems deployment KPI's complete description can be found in deliverable 1.4 [4].

5.1.2. Standardisation and interoperability

REACT platform must use open standards to facilitate the integration with the existing systems. The standardisation and interoperability KPI have the objective to check if the protocols implemented in the platform conform to a protocol standard. This KPI will measure the use of standards among devices, equipment, and the platform to calculate the percentage of the standard protocols in the project.

Targeted Metric:

Comply with interoperability standards (SG-CG, IEC 61970 (CIM), IEC 61850, Open ADR).

Inputs:

- Number of standard protocols implemented in REACT project
- Number of total protocols implemented in REACT project

Outputs:

- Percentage of implemented standard protocols in the project [%]

Equations:

$$\text{Standardisation and Interoperability [\%]} = \frac{\sum \text{Standard Protocols}}{\sum \text{Number of total protocols}} * 100$$

Equation 8 - KPI - Standardisation and Interoperability [4]

5.1.3. Validation of the Integration

This KPI quantifies devices at demonstration scenarios that have been integrated with the platform for sending data and receiving control commands. The assessment method will be a verification process to check if each device has been integrated. The results represent the percentage of devices integrated with the REACT platform.

Targeted Metric:

Reach TRL 7-8 in 3 pilots

Inputs:

- Number of devices integrated to the REACT platform
- Total number of devices available to integrate

Outputs:

- Percentage of the devices integrated with the REACT platform [%]

Equations:

$$Integration [\%] = \frac{\text{Number of devices integrated}}{\text{Number of total devices}} * 100$$

Equation 9 - KPI - Validation of integration [4]

Based on the outcomes of this KPI, the Technology Readiness Level (TRL) achieved by the pilot can be specified. Figure 15 shows the TRL levels specification:

| TECHNOLOGY READINESS LEVEL (TRL) | | |
|----------------------------------|---|-----------------------------------------------------------|
| DEVELOPMENT | 9 | ACTUAL SYSTEM PROVEN IN OPERATIONAL ENVIRONMENT |
| | 8 | SYSTEM COMPLETE AND QUALIFIED |
| | 7 | SYSTEM PROTOTYPE DEMONSTRATION IN OPERATIONAL ENVIRONMENT |
| | 6 | TECHNOLOGY DEMONSTRATED IN RELEVANT ENVIRONMENT |
| | 5 | TECHNOLOGY VALIDATED IN RELEVANT ENVIRONMENT |
| | 4 | TECHNOLOGY VALIDATED IN LAB |
| RESEARCH | 3 | EXPERIMENTAL PROOF OF CONCEPT |
| | 2 | TECHNOLOGY CONCEPT FORMULATED |
| | 1 | BASIC PRINCIPLES OBSERVED |

Figure 15 - Technology readiness level (TRL) [60]

5.1.4. Maximisation of intermittent RES utilisation

Microgrid systems are either isolated, mutually interconnected or connected to a larger energy transmission system. Depending on the considered use case, a different subset of parameters can be used (i.e., in a system without the possibility of exporting RES generation, net exported energy may not be an insightful characteristic). In Deliverable 1.4 [4], for this KPI there is a selection of RES utilisation measurements defined. However,

in this deliverable just one defined equation will be included to validate this metric. The measurement will be the total on-site generation being used locally.

Targeted Metric:

Up to 100% utilisation of RES

Inputs:

- $g(t)$ - RES instantaneous generation [W]
- $S(t)$ - Instantaneous storage charge/discharge rate [W]
- $\zeta(t)$ - Instantaneous power of losses [W]
- $l(t)$ - Instantaneous energy demand load value [W]

Outputs:

- γ_{supply} - Percentage of the local renewable energy consumption [%]

Equations:

$$\gamma_{supply}[\%] = \frac{\int_{t_1}^{t_2} \min\{g(t) - S(t) - \zeta(t), l(t)\} dt}{\int_{t_1}^{t_2} g(t) dt} * 100$$

Equation 10 - KPI - Supply load factor [4]

5.1.5. Ensured grid stability and grid uptime

When assessing grid status, considering renewable generation and load levels is important. To measure the uptime improvements in the grid, the focus of this report will be in periods where the local generation does not cover the building demand and the energy must be supplied by the grid. For information about other possible approaches related to this topic, please refer to Deliverable 1.4 [4].

Targeted Metric:

5% grid uptime improvements

Inputs:

- $f(t)$ – Auxiliary function that represents an indicator of net energy export/import

Outputs:

- Fraction of time when 100% of the load can be matched by on site generation

Equations:

$$\text{Energy autonomy} = 1 - \frac{\int_{t_1}^{t_2} f(t)}{t_1 - t_2}$$

Equation 11 – Energy autonomy [4]

To calculate the uptime improvement, it will be necessary to create a baseline value for the energy autonomy before the control action implementation.

5.1.6. Measurement validation

This KPI is set to guarantee that the validation process is considering relevant and already approved protocols to validate the project. To be adherent to the IPMVP, according to the protocol, it is necessary to ensure the development and implementation of a clear and transparent project-specific M&V Plan. To achieve the outcomes proposed by the M&V plan, data quality needs to be considered. The validation of this KPI will be based on the quantity of data collected in the validation phase, since a proper collection of reliable measurements of the energy variables during the project is necessary to apply the IPMVP options properly.

Targeted Metric:

Validations as per IPMVP and eeMeasure

Inputs:

- Number of measurements expected in the period
- Number of measurements at the REACT platform

Outputs:

- Percentage of measurement validation considering the quality of the data stored in the platform

Equations:

$$\text{Measurement validation [\%]} = \frac{\text{Number of measurements at the REACT platform}}{\text{Number of measurements expected in the period}} * 100$$

Equation 12 - KPI - Measurement Validation

5.1.7. Real-time health monitoring of the grid

Monitoring grid health in real-time is a vast task. In REACT there are monitoring devices installed to collect information in real time about the parameters of the grid. To validate the targeted metric, It will be considered the demand profile of the micro-grid being analysed. When the microgrid has the objective to offset 10% of the energy consumed by the grid.

Targeted Metric:

10% forecast offset corresponding to actual generation/demand profile

Inputs:

- $Grid(t)$ - Energy provided by the grid [kWh]
- $RES(t)$ - Renewable energy generation [kWh]

Outputs:

- Percentage of energy being provided by the grid

Equations:

$$\text{Energy consumption} = \frac{\int_{t1}^{t2} \{Grid(t) - RES(t)\} dt}{\int_{t1}^{t2} Grid(t) dt} * 100$$

Equation 13 - Energy consumption by the grid

5.2. Environmental

KPIs in the environmental domain are intended to evaluate the impact of the use of renewable generation and storage to reduce the need of energy from the grid. The targeted metrics of this category are:

- 100% RES utilisation
- 60% energy cost reduction
- 100% energy autonomy
- 50% increase RES penetration
- 60% GHG reductions

These metrics are related to the STO3 and STO5.

5.2.1. Level of energy autonomy

This KPI is a metric to analyse the ratio of the total amount of renewable energy produced compared to the total demand in a defined period.

Targeted Metric:

100% RES utilisation

Inputs:

- $RES(t)$ - Renewable energy generation [kWh]
- D - Energy demand [kWh]

Outputs:

- Percentage of the renewable energy consumption

Equations:

$$RE[\%] = \frac{RES(t)}{D} * 100$$

Equation 14 - KPI – Percentage of renewable energy consumption [4]

5.2.2. Energy cost reduction due to RES and reduction of hydrocarbon fuels

When there is installation of RES, and the system is performing in its best considering the usage of control actions for improvement and storage systems for the best usage of the energy there is a reduction in the cost.

The following KPI is used to calculate the variation in the costs considering the value of energy being used just by the grid, and the value with the usage of RES.

Targeted Metric:

60% energy cost reduction

Inputs:

- EP_{grid} - Energy price considering the usage of the grid [euros]
- EP_{RES} - Energy price considering the reduction due to RES [euros]

Outputs:

- Percentage of energy cost reduction [%]

Equations:

$$\text{Energy cost reduction} = \frac{EP_{grid} - EP_{RES}}{EP_{grid}}$$

Equation 15 - KPI - Percentage of energy cost reduction

5.2.3. RES maximisation to avoid idle capacity

To maximize the RES utilisation is also to guarantee that the level of energy autonomy of the participant is increasing. To calculate this targeted metric, the same formula used in the level of energy autonomy will be applied.

Targeted Metric:

100% energy autonomy

Inputs:

- $RES(t)$ - Renewable energy generation [kWh]
- D - Energy demand [kWh]

Outputs:

- Percentage of the renewable energy consumption

Equations:

$$RE[\%] = \frac{RES(t)}{D} * 100$$

Equation 16 - KPI - RES maximization [4]

5.2.4. RES penetration

To increase the RES penetration is one of the targets of the project. The KPI RES penetration has the objective to quantify the penetration of renewable energy generation for a specified period.

Targeted Metric:

50% increase RES penetration

Inputs:

- Renewable energy produced [kWh]
- Energy consumed [kWh]

Outputs:

- Percentage of renewable energy penetration [%]

Equations:

$$RES \text{ penetration } [\%] = \frac{REp}{Ec} * 100$$

Equation 17 - KPI - RES penetration [4]

5.2.5. GHG reductions

The GHG reductions KPI has the objective to quantify the CO₂ reductions that were achieved by the REACT project actions. This KPI calculation will be based on the energy savings achieved in the studied period.

Targeted Metric:

60% GHG reductions

Inputs:

- EF_{source} – Emission factor of CO₂ considering local information [kgCO₂/kWh]
- Energy being saved by the DR action [kWh]

Outputs:

- CO₂ reduction [kgCO₂]

Equations:

$$CO_2Reduction = Energy\ Savings * EF_{source}$$

Equation 18 - KPI GHG reductions

To achieve the percentage of GHG reductions, it is necessary to also calculate the CO₂ for the adjusted baseline for the respective use case.

5.3. Economical

The economical KPIs are important to understand the health of the project considering the investments. The metrics that are going to be calculated in the economic KPIs are:

- Replication plans & business models for “follower” islands
- 20% OPEX reductions
- 10% energy savings
- 10% increased efficiency
- 60% energy cost reduction

- Validation at 3 demo and plans for 5 “follower” islands
- 60% energy cost savings

These metrics are related to the STO1, STO2, STO5 and STO6.

5.3.1. Replication potential

The replication potential of the project is evaluated on task 7.4. The deliverable 7.4 contains guidelines detailing the replication planning for REACT solutions in the demo islands, in the follower islands and beyond. Since the replication plan is considered one task of the REACT project, this metric should be evaluated by the task 7.4.

5.3.2. Grid OPEX reductions

The operational expenditures variation is a KPI to analyse the savings of the project in terms of operations. After the OPEX calculation, the objective is to calculate the variation comparing the reduction to the baseline period. For more information about how to calculate the OPEX of the project, please refer to Deliverable 1.4 [4].

Targeted Metric:

20% OPEX reductions

Inputs:

- $OPEX_{BL}$ – OPEX before the EEM implementation
- $OPEX_{Actual}$ – OPEX after the EEM implementation

Outputs:

- ΔEC_o – Economic variation cost savings [%]

Equations:

$$\Delta EC_o = \frac{OPEX_{BL} - OPEX_{Actual}}{OPEX_{BL}} * 100$$

Equation 19 - Percentage of OPEX reduction

5.3.3. Energy savings

Energy savings is the reduction of energy consumption compared to an adjusted energy baseline [13]. Based on the IPMVP protocol, the method to calculate the energy savings can be found in item 3.1.1 of this report. In this section, there will be the formula provided by the IPMVP to accurately measure the energy savings of the project, and it will be considered that the increased efficiency will be achieved in case of the project achieve the 10% of energy savings maintaining or enhancing the comfort of the participant.

Targeted Metric:

10% energy savings

10% increased efficiency

Inputs:

- Energy baseline period [kWh]
- Reporting period [kWh]
- Adjustments [kWh]
- Energy baseline period adjusted [kWh]

Outputs:

- Energy savings for the project [kWh]

Equations:

$$Savings = (Baseline\ Period\ Energy - Reporting\ Period\ Energy) \pm Adjustments$$

Equation 20 - KPI - Energy savings [12]

$$Savings\ [\%] = \frac{Savings}{Baseline\ Period\ Energy\ adjusted}$$

Equation 21 - KPI - Energy savings [%]

5.3.4. Energy costs reductions

The following KPI is used to quantify the reduction of the costs of energy used from the grid in a period. This KPI is the variation between the adjusted baseline energy demand and the real energy demand.

Targeted Metric:

60% energy cost reduction

Inputs:

- Savings [kWh]
- Energy price [€]

Outputs:

- Energy cost reduction [€]

Equations:

$$\text{Energy cost reduction} = \text{Savings} * \text{Energy Price}$$

Equation 22 - KPI - Energy cost reduction

To variable values of tariff in different periods, the price variation should also be considered in this calculation.

5.3.5. Business model demonstration

To validate the success of the proposed business models it is important to monitor the degree of fulfilment of the objectives defined. For that goal the following KPI is suggested, considering that a clear definition of the business models is necessary for a correct supervision:

Targeted Metric:

Validation at 3 demo and plans for 5 “follower” islands

Inputs:

- Number of objectives fulfilled
- Number of total objectives

Outputs:

- Business model demonstration

Equations:

$$\text{Business model demonstration [\%]} = \frac{\text{Number of objectives fulfilled}}{\text{Number of total objectives}} * 100$$

Equation 23 - KPI - Business model demonstration [4]

5.3.6. Economical savings for end consumers

This KPI has the objective to measure the economical savings from an end consumer's point of view. Within this aim, the following equation expresses the annual energy bill savings in the year following the project implementation relative to the annual energy bills total in the baseline period before the project implementation. To guarantee that the energy expenses are being evaluated correctly, it is necessary to create an adjusted baseline with the relevant adjustments for the period.

Targeted Metric:

60% energy cost savings

Inputs:

- Total energy bills expense before REACT [€]
- Total energy bills expense after REACT [€]

Outputs:

- Economic savings for the end consumers [€]

Equations:

$$\text{Economic savings [\%]} = \frac{\text{energy bills before REACT} - \text{energy bills after REACT}}{\text{energy bills before REACT}} * 100$$

Equation 24 - KPI - energy savings for the end consumers [4]

5.4. Social

Social KPIs will be evaluated considering both the qualitative and the quantitative analysis. To validate the targeted metrics, some equations are proposed in this section. The REACT objectives to be validated are:

- 90% acceptance rate
- 80% actively involved in DR activities
- 6 workshops organized, 6 journal publications, etc.

These metrics are related to the STO4 and STO6.

5.4.1. Consumer acceptance

To validate the consumer acceptance in the project in a quantitative manner, it will be considered the information collected by the REACT app. The app has a feedback notification feature, that allows users to accept an action and give feedback about it. This KPI will be applied in cases where an action from the consumer is necessary. For more information about the functionality, please go to Deliverable 6.4 [9].

Targeted Metric:

90% acceptance rate

Inputs:

- Number of inputs received from the end consumers
- Number of inputs accepting the DR action

Outputs:

- Percentage of acceptance rate [%]

Equations:

$$Acceptance\ Rate[\%] = \frac{Total\ inputs\ received - positive\ inputs}{Total\ inputs\ receives} * 100$$

Equation 25 - KPI - Acceptance rate

5.4.2. User engagement and participation in DR programs

Similar to the consumer acceptance KPI, to validate the user engagement in a quantitative manner, it will be considered the information collected by the REACT app. To calculate this KPI, the information about the feedback will be checked, and also the outcomes from action. If during the period, the user performed an action as suggested by the platform even not sending the feedback message the action may be considered as a positive outcome and be included in this calculation.

Targeted Metric:

80% actively involved in DR activities

Inputs:

- Number of users contacted
- Positive inputs in the app
- Positive outcomes from the data analysis

Outputs:

- Percentage of the user engagement [%]

Equations:

$$User\ engagement\ [\%] = \frac{Total\ messages\ sent - positive\ inputs - positive\ results}{Total\ messages\ sent} * 100$$

Equation 26 - KPI - User engagement

5.4.3. Dissemination activities

This KPI aims to validate the number of dissemination activities performed during the project period. Any dissemination activity may be considered, as an example workshops organization and journal publications.

Targeted Metric:

6 workshops organized, 6 journal publications, etc.

Inputs:

- Number of dissemination activities performed

Outputs:

- Summatory of the number of the dissemination activities

Equations:

$$\text{Dissemination activities} = \sum \text{activities performed.}$$

Equation 27 - KPI - Dissemination activities

6. Definition of project Use Cases

The use cases presented in this chapter are based on the information obtained on the REACT WP 01 deliverable 1.3 [3]. Each use case will use a different set of devices that are installed in the pilots. Figure 16 shows the conditions to the application of the assets control considering the optimisation process, and the automation demand response level characteristics.

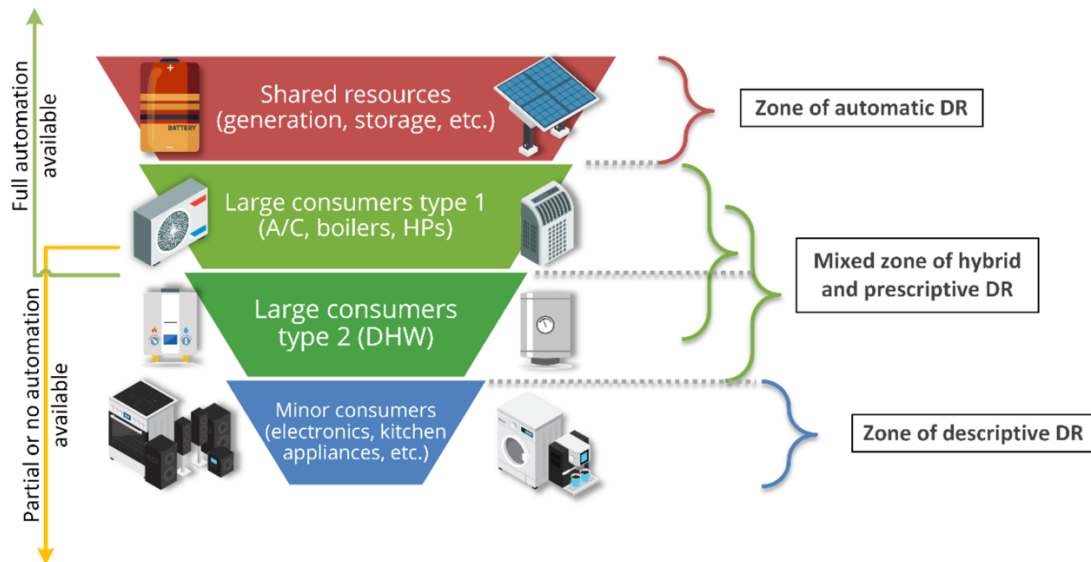


Figure 16 - Different types of control foreseen with REACT [2]

In this section there will be indication of the ideal characteristics of the Use Cases to be applied. The objectives, operation, DR type, pilot location and the buildings, dates of the events, the indicated baseline type, IPMVP option to be applied, the preconditions to apply the events, the devices involved, and the KPIs to validate.

It is important to consider that in some cases it is not possible to isolate which control action is being applied in a specified period, since the platform may take an action based on the best scenario for the specified period. In these cases, it may be considered for the validation the aggregated value for all the buildings and not the result for a specific action.

6.1. DR Action 1 - Storage management

In cases of overproduction or underproduction from local RES, working in periods with lower energy costs or higher energy costs, or an unexpected decrease or increase of load occurs, the storage should be charged or discharged respectively using adequate control protocols so that the mismatch between generation and demand is absorbed. REACT will incorporate a number of battery solutions to increase the share of renewables in final consumption, offering energy buffering and ensuring grid stability and resilience.

Objective: Charge or discharge the storage system using control actions to adjust the energy demand being consumed by the grid.

Operation: REACT control loop verifies the energy consumption comparing to the energy production and charge or discharge the battery when necessary.

DR description: Load shifting

DR type: Automated

Pilots: Ireland, Spain and Italy

Possible participant buildings: AI1, AI2, AI3, AI4, AI5, AI6, AI7, AI8, AI9, AI10, AI11, AI12, AI13, AI14, AI15, AI16, AI17, AI18, AI19, SP101, SP102, SP105, SP108, SP4, SP9, SP10, SP13, SP33, SP35, SP36, SP37, SP38, SP39, SP40, SP47, SP48, SP50, SP51, SP54, SP55, LG2.1, LG2.2, LG3, LG4, LG11, LG13, LG15, LG16, LG17, LG18, LG27, LG24, LG25, LG30, LG35, LG41, LG44, and LG45.

Event Start: 01/07/2022

Event ends: 31/08/2022

IPMVP option: Option C

Indicated baseline method: REACT Demand Forecast

Indicated period of baseline collection: 01/05/2022 – 30/06/2022

Pre-conditions: Mismatch between local production and demand, and storage management system control available.

Devices:

- Storage systems
- Inverters

Core Services:

- Production forecast
- Demand forecast
- Data repository
- Battery controller

Related KPIs:

- Validation of the Integration
- Maximisation of intermittent RES utilisation
- Ensured grid stability and grid uptime
- Measurement validation
- Real-time health monitoring of the grid
- Level of energy autonomy
- Energy cost reduction due to RES and reduction of hydrocarbon fuels
- RES maximisation to avoid idle capacity
- RES penetration
- GHG reductions
- Energy Savings
- Energy costs reductions
- Economical savings for end consumers

6.2. DR Action 2 – Maximising self-consumption

Enhancing the self-consumption using the storage systems installed, the utilisation of locally produced energy is maximized. This way, minimising the energy that is imported from the grid and improving the autonomy of energy in the islands. Employment of battery storage will minimize the discrepancy between intermittent renewable energy generation and consumer demand while maintaining grid stability and reliability.

Objective: Charge or discharge the storage system using control actions to adjust the energy demand being consumed by the consumer.

Operation: REACT control loop verifies the demand energy consumption and charge or discharge the battery when necessary, avoiding the usage of energy from the grid.

DR description: Peak clipping

DR type: Automated

Pilots: Ireland, Spain and Italy

Possible participant buildings: AI1, AI2, AI3, AI4, AI5, AI6, AI7, AI8, AI9, AI10, AI11, AI12, AI13, AI14, AI15, AI16, AI17, AI18, AI19, SP101, SP102, SP105, SP108, SP4, SP9, SP10, SP13, SP33, SP35, SP36, SP37, SP38, SP39, SP40, SP47, SP48, SP50, SP51, SP54, SP55, LG2.1, LG2.2, LG3, LG4, LG11, LG13, LG15, LG16, LG17, LG18, LG27, LG24, LG25, LG30, LG35, LG41, LG44, and LG45.

Event Start: 01/07/2022

Event ends: 31/08/2022

IPMVP option: Option C

Indicated baseline method: REACT Demand Forecast

Period of baseline collection: 01/05/2022 – 30/06/2022

Pre-conditions: Existence of local generation and controllable storage, and a mismatch between the local production and demand.

Devices:

- RES system
- Storage systems
- Inverters
- Battery controller

Core Services:

- Production forecast
- Demand forecast
- Data repository
- User Adapter

Related KPIs:

- Validation of the Integration
- Maximisation of intermittent RES utilisation
- Ensured grid stability and grid uptime
- Measurement validation
- Real-time health monitoring of the grid
- Level of energy autonomy
- Energy cost reduction due to RES and reduction of hydrocarbon fuels
- RES maximisation to avoid idle capacity
- RES penetration
- GHG reductions
- Energy Savings
- Energy costs reductions
- Economical savings for end consumers

6.3. DR Action 3 - Using locally produced energy for feed-in

In cases of overproduction from local renewable sources, the excess generation from the islands can be directed towards the grid. This use case objective is to not lose this energy, by sending this excess to the grid.

Objective: When there is no energy demand in the building, and the energy storage system is fully charged, send the excess of energy produced to the grid.

Operation: When there is an excess of energy generation not being consumed by the residence, the system should perform a feed-in the grid.

DR description: Load shifting

DR type: Automated

Pilots: Ireland, Spain and Italy

Possible participant buildings: AI1, AI2, AI3, AI4, AI5, AI6, AI7, AI8, AI9, AI10, AI11, AI12, AI13, AI14, AI15, AI16, AI17, AI18, AI19, SP102, SP104, SP105, SP108, SP4, SP9, SP10, SP33, SP35, SP36, SP38, SP39, SP40, SP48, SP55, SP100, LG1, LG2.1, LG2.2, LG3, LG4, LG7, LG9, LG11, LG13, LG15, LG16, LG17, LG18, LG24, LG25, LG27, LG30, LG35, LG41, LG44, and LG45.

Event Start: 01/07/2022

Event ends: 31/08/2022

IPMVP option: Option C

Indicated baseline method: REACT Demand Forecast

Period of baseline collection: 01/05/2022 – 30/06/2022

Pre-conditions: Existence of local generation and a smart meter installed able to send energy to the grid.

Devices:

- Local RES
- Smart meters

Core Services:

- Production forecast
- Demand forecast
- Data repository
- Assets controller

Related KPIs:

- Validation of the Integration
- Ensured grid stability and grid uptime
- Measurement validation

6.4. DR Action 4 - End-user appliance control

In order to make use of extended load flexibility, the users can be directed on how and when to use their appliances having in mind predicted energy generation and storage levels. The objective of this use case is to maximize the self-consumption during peaks of energy production. The hourly production prediction model estimates the PV production, and this information can be used to send a message to the participants using the REACT app, asking them to increase the energy usage during this period to increase the self-consumption.

Objective: Increase the self-consumption of energy during a specified period sending a message to the participant asking them to increase the consumption.

Operation: When a specific threshold is achieved in the production predictions, a message is sent to the participant asking for increasing the energy usage in a specified period to increase the self-consumption of the RES to decrease the energy consumption from the grid in other periods.

DR description: Load shifting

DR type: Prescriptive, Descriptive

Pilots: Ireland, Spain and Italy

Possible participant buildings: AI1, AI2, AI3, AI4, AI5, AI6, AI7, AI8, AI9, AI10, AI11, AI12, AI13, AI14, AI15, AI16, AI17, AI18, AI19, SP102, SP104, SP105, SP108, SP4, SP9, SP10, SP33, SP35, SP36, SP38, SP39, SP40, SP48, SP55, SP100, LG1, LG2.1, LG2.2, LG3, LG4, LG11, LG13, LG15, LG16, LG17, LG18, LG24, LG25, LG27, LG30, LG35, LG41, LG44, LG45, LG7, and LG9.

Event Start: 01/09/2022

Event ends: 30/09/2022

IPMVP option: Option C

Indicated baseline method: REACT Demand Forecast

Period of baseline collection: 01/05/2022 – 30/06/2022

Pre-conditions: Existence of communication channel between the platform and end users, and existence of local renewable energy generation.

Devices:

- Domestic appliances
- Local RES

Core Services:

- Production forecast
- Demand forecast
- Data repository
- User Adapter
- Consumer Recommender

Related KPIs:

- Validation of the Integration
- Maximisation of intermittent RES utilisation
- Ensured grid stability and grid uptime
- Measurement validation
- Real-time health monitoring of the grid
- Level of energy autonomy
- Energy cost reduction due to RES and reduction of hydrocarbon fuels
- RES maximisation to avoid idle capacity
- RES penetration
- GHG reductions
- Energy Savings
- Energy costs reductions
- Economical savings for end consumers
- Consumer acceptance
- User engagement and participation in DR programs

6.5. DR Action 5 - Optimising HP operation

Considering thermal comfort flexibility, heat pumps can be used in the load optimisation workflow so that they are adapted to current conditions (e.g. higher or lower RES production, energy consumption, optimal consumption profile). For this, the building simulator will be used to predict the best usage pattern and a control action will be issued to the heat pump system, scheduling the best usage time of the heating or cooling systems and domestic hot water systems, to keep the house comfort. For this use case, two different scenarios will be considered, one for the heating system in the Irish pilot in the autumn, and another for the cooling system in the Italian pilot in the summer.

Objective: The objective of this use case is to change the usage pattern of the heat pump to decrease the energy consumption from the grid maintaining the comfort level of the participant.

Operation: The day before the event, a control action will be send to the heat pump with the best hourly pattern to keep the comfort level and decrease the energy consumption.

DR description: Load shifting

DR type: Automated

Pilots: Ireland and Italy

Possible participant buildings: AI2, AI4, AI22, AI25, SP13, SP9, SP16, SP17, SP18a, SP23, SP105 and SP107.

Italian pilot: (Summer)

Event Start: 01/07/2022

Event ends: 31/08/2022

Irish Pilot: (Autumn)

Event Start: 01/10/2022

Event ends: 31/10/2022

IPMVP option: Option B

Indicated baseline method: REACT Demand Forecast

Period of baseline collection: 01/05/2022 – 30/06/2022

Pre-conditions: Availability of remote controls for HPs

Devices:

- Heat pumps
- Local RES

Core Services:

- Production forecast
- Demand forecast
- Building simulator
- Data repository
- Heat Pumps controller

Related KPIs:

- Validation of the Integration
- Maximisation of intermittent RES utilisation
- Ensured grid stability and grid uptime
- Measurement validation
- Real-time health monitoring of the grid
- Level of energy autonomy
- Energy cost reduction due to RES and reduction of hydrocarbon fuels
- RES maximisation to avoid idle capacity
- RES penetration
- GHG reductions
- Energy Savings
- Energy costs reductions
- Economical savings for end consumers

6.6. DR Action 6 - Battery reactive power control

Based either on a fixed setpoint or a set power factor, the inverters and batteries can be controlled so that the corresponding reactive power level is maintained.

Objective: Use the battery to control the reactive power

Operation: Hardware in the loop tests were performed in this regard. The reactive power will be measured and control actions will be performed to adjust the parameter.

DR description: Peak clipping

DR type: Automated

Pilots: Ireland

Possible participant buildings: AI1, AI2, AI3, AI4, AI5, and AI6

Event Start: 01/07/2022

Event ends: 31/08/2022

IPMVP option: Option B

Indicated baseline method: Top average 3 of 10 days baseline

Period of baseline collection: 20/06/2022 – 30/06/2022 (considering the moving average for days with event).

Pre-conditions: Regulatory support, power quality issues.

Devices:

- Energy storages
- Inverters

- Smart meters

Core Services:

- Data repository
- Battery controller

Related KPIs:

- Validation of the Integration
- Measurement validation
- Energy cost reduction

6.7. DR Action 7 - Frequency and voltage-based battery power controls

In cases with power quality issues, the REACT assets could be utilized within grid supportive services that attempt to maintain the power supply at desired capacity. For this, REACT will demonstrate the reliable operation of grid using hardware in the loop testing. REACT is deploying real-time testing of low voltage micro-grids as part of the hardware in the loop testing facility going beyond a typical scientific test feeder topology and move closer to real-world topology testing, with validation of the method in the field, such as the operation phase of the grid after the introduction of RES generation and storage systems.

Objective: Control of frequency and voltage-based battery power controls

Operation: Hardware in the loop tests were performed in this regard. The frequency and voltage controls will be measured and control actions will be performed to adjust the parameter when necessary.

DR description: Frequency and voltage control

DR type: Automated

Pilots: Ireland

Possible participant buildings: AI1, AI2, AI3, AI4, AI5, and AI6

Event Start: 01/07/2022

Event ends: 31/08/2022

IPMVP option: Option B

Indicated baseline method: REACT Forecast

Period of baseline collection: 01/05/2022 – 30/06/2022

Pre-conditions: Regulatory support, power quality issues

Devices:

- Energy storages
- Inverters

Core Services:

- Data repository
- Battery controller

Related KPIs:

- Validation of the Integration
- Measurement validation
- Energy cost reduction

7. Discussion and Conclusions

The main objective of this report was to create an M&V process based on the steps designed by the IPMVP protocol, and to aggregate all the necessary information for the validation process from other REACT deliverables in one document to provide a guidance in the calculation of the project results.

The project KPIs were revisited to guarantee that the targeted metrics were being evaluated considering the devices installed in the pilots. Some of them were updated for a better understanding and to facilitate the calculation of the targeted metrics. All the updated formulas were included in this document.

Although this deliverable aim to guide in the most reliable way how to perform the calculations based on what the platform is providing, some amendments may be needed according to the final deployment characteristics. Adjustments according to the use case may be realized to create the adjusted baseline using weather, data quality, energy tariff increases, or any other relevant factor for the analysed period. This information should be included in deliverable 7.2 when describing the reporting period.

The use cases have the objective to run different components of the system (i.e., forecasting, optimization, building models and grid capacity management) and evaluate their inputs and outputs and how they connect to subsequent services observing the impact that the actions have on the energy assets. If a Use Case has a regulation issue that prevents the tests to be accomplished, it is advised to perform the validation of these DR action using the IPMVP option D.

The Use Cases description in this report are based on previous REACT deliverables and are considering the installations specificities deployed by the project so far, which may have some updates until the report period. The dates, type of baseline creation, or any other characteristic of the Use Cases that may be adjusted during the validation implementation should be described in deliverables 7.2 and 7.3.

The platform takes actions based on the best scenario for the specified period for the building. It is important to consider that in some cases it may not be possible to isolate which control action is being applied. In these cases, it should be considered for the validation of the targeted metrics the KPI calculation for the analysed period.

Finally, the proposed M&V plan stressed a number of validation options to handle different types of situations that may occurs during the reporting period of the current pilots or in the implementation in the following islands.

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